Technology Transfer and the Acquisition of Technological Capabilities: the Development of Public Digital Switching Technology in China

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To the memory of

my father, Bai-Yu Shen

Declaration

I, Xiaobai Shen, hereby declare that this thesis has been composed by myself, and the work is my own.

Signature

5. 9. 1997

Date

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This thesis examines the scope for developing countries, and in particular those with a socialist tradition like China, to benefit from advanced technologies developed in the West and acquire indigenous technological capacities. Empirically it investigates China's attempts to acquire capabilities in the highly complex field of - Public Digital Switching Systems (PDSS) - the technology at the heart of modern telecommunications systems and therefore of great social and economic importance.

The study builds upon a critical review of literature in three areas: development studies, studies of socialist economies and technology studies. It explores how developing countries might utilise exogenous technological competencies effectively, by means of 'dual technology development' with appropriate strategies for technology transfer and processes of technological learning to transform exogenous competencies into indigenous ones.

Two detailed cases studies are presented and analysed in the wider social and economic context. One involves the wholesale transfer of capabilities to produce a Western PDSS technology in China (System 12) through a joint venture project. The other involves the indigenous development of a Chinese PDSS (HJD-04) conceived by a military R&D institute, and brought to production through a collaboration with two other bodies in the Chinese telecommunication sector. These cases highlight the range of choices available in the acquisition of technological capabilities - from large scale and formal technology transfer (System 12), which provided a wide range of means for technological learning, to the selective import of component technologies (HJD-04) and their effective combination with locally available expertise. They offer different opportunities for further innovation and for local shaping of these technologies.

The cases also throw light on the influence of the economic reforms on the technological dynamism of China's 'national system'. In particular, the introduction of market pressures provided important incentives for R&D institutes and producers to become more responsive to their customers and to work together. Economic necessity forced them to compete in the market and meet customers' requirements for high product quality. The cases demonstrate the need for continued state intervention to provide frameworks for market mechanisms to encourage technological co-operation, to balance local and national interests, and to reduce negative social consequences. In light of the changing and diverse forms of state intervention in China, the thesis argues that market dynamics and public policy should be complementary.

Table of Contents

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PART I: BACKGROUND TO THE STUDY

Chapter 1:

Introduction

1.1 Focus and Scope of Study

The main theme which concerns me in this study is technology development in developing countries. This basically involves two elements. The first is the transfer of advanced technologies from industrialised countries, and the various options and strategies through which a nation may seek to build up indigenous technological capabilities. The second concerns restructuring a country's socio-economic system for technological development. This study focuses on a socialist state, the People's Republic of China, which is transforming its system from a centrally planned to a market-oriented one, and pursuing development through a combination of state intervention and market forces. Specifically, it deals with the development of public digital switching technology (PDSS) in the context of China's economic transition.

The empirical research looks into acquisition of technological capabilities in the area of public digital switching systems (PDSS), focusing on two contrasting cases: in the first, foreign technology is transferred, as a complete system, into China through a joint venture project; the other is a locally developed system which utilises available foreign components and design tools. The study examines these two different strategies for utilising advanced foreign technologies as well as their outcomes. It explores in the detail the processes of development and adaptation of technology involved in these two systems, the social and economic driving forces behind them, and their roots in China's economic transition. It examines the changes in the behaviour of, and relationships between, actors (individuals or organisations) involved in these processes - e.g. a military R&D institute, a state-owned firm, a joint production venture, and other relevant governmental organisations - focusing in particular on the roles played by the state and the newly-introduced market mechanisms in China.

This introductory chapter briefly outlines the intellectual traditions that have underpinned the approach of this study. It then addresses the importance of the telecommunications sector and, finally, describes the context of the study in China's economic and social system.

1.2 Intellectual Underpinnings of the Study

This research applies the approach of "social shaping of technology" to the case of telecommunications technology development in China. It examined the detailed process of technological development, to understand the interactive linkage between technological development and the social, economic and political agents and environment wherein the technological process operates. Unlike many economic approaches, which treat the complex value systems of human society in a simplified manner as if they were uniform, this research takes other elements involved in the technological process into account, e.g. cultural inheritance, political tradition, historical experiences. In contrast to most policy related research which focuses on the macro level, this study investigates the effects of the policies relevant to building up technological capabilities and gaining technological competencies at the level of the individual R&D team, firms and management institutions.

Because technologies like telecommunications have an enormous impact on social, economic and political life, its development is of great concern to all these social, economic and political agents. However, the quest for a comprehensive overview of the interaction between technical and social, political and economic elements adds enormous complexity to this research. At the same time, the complexity of the socio-economic issues addressed - in relation to both the technological development and to the China's socio-economic transition - makes this study extraordinarily broad. Issues touched in this research span at least three disciplinary areas: development studies, the study of socialist economics (in particular the current transition of socialist states) and technology studies.

In development studies, a long standing debate has surrounded whether developing countries should import advanced foreign technologies, which may be largely inappropriate to the local conditions and which have more or less embedded in them Western values and rationales; does this lead to dependencies of different sorts and negative social consequences? The experiences of newly industrialised countries (NICs), particularly the four Asian NICs, suggests that developing countries do indeed have opportunities to leapfrog into the new technological era based on electronics and information technologies from the West. This has prompted more recent debates on whether the state should pursue the role of directing investment and activities in technology development and protecting domestic industries, and what state interventions both direct and indirect are appropriate? Though these debates are not new to this field, they nevertheless are still academically controversial and are of great concern to all developing countries. This research seeks to examine these debates in the light of Chinese experiences, and their relevance for the policy challenges facing China today.

China had adopted a socialist model of development for thirty years before its recent economic reforms, though this differed from the widely used Soviet model to some extent. Moreover, while many former socialist states have abandoned socialism, China is till hanging on to some elements of the socialist path in its economic transition. Therefore, issues related to the study of socialist economics and transitions are thrown up by this research. Apart from briefly confronting the heated debates on the compatibility or incompatibility of socialism and market mechanisms and the future of socialism, this research analyses the Chinese socialist tradition in relation to technological development and the transition to a more market-oriented economy. And it examines their related institutions and government policies which have had a major impact on the technological dynamism of the country in the past and now.

In the area of technology studies, there have been important developments in understanding of the process of technological innovation. However, a vigorous and systematic analysis for investigation of the social determinants of technological change across different (economic, social and technological) contexts is still lacking. This is particularly the case in relation to the developing countries, given the focus of most technology studies on the advanced Western economies. The study explores whether and how insights from technology studies can be applied in developing countries and China in particular.

This study treats development as a strategic matter, and one that involves a competition between individual countries, developed and developing alike. It argues that, despite particular constraints, there are opportunities for less developed countries to catch up to some extent. There is thus a need to identify these opportunities and establish a series of appropriate strategies for the long and short term development of a nation. It stresses that the development of appropriate strategies depends on understanding of not only the external environment but also internal strengths and weaknesses.

The Chinese socialist tradition is also brought under scrutiny, so is its economic transition along "socialist path". With respect to existing socialist theories and practices, this study suggests that the better choice for China is to combine socialism and market and integrate state intervention and market forces to balance the interests of the whole society and the efficiency of economic development. From the viewpoint of development strategies, whether China is truly socialist is not the issue. More important is the speed and continuity of China's development, not only in economic but also social and political terms. There are interesting comparisons with the former Soviet Union and other Eastern European countries which appear to have abandoned their socialist tradition over night and lost much of state power.

The standpoint of this research is optimistic about the possibility for developing countries to catch up in the new era of information technology based on micro-electronics. With the current trends of globalisation of technological development, issues of national strategies for technology development have come to the fore, for developed as well as developing countries. The enormous development costs and complexity of these technologies mean that only the very largest and most advanced economies can hope to have the full range of technological competencies. Globalisation thus poses both limits and opportunities on national strategies. In particular, the application of different strategies can alter the position of a country from one which solely favours external high-technology suppliers to one which also meets the interests of the developing countries seeking to acquire the technology.

The success of Asian NICs has stimulated interest in the matter of high-technology development and developing countries. This study supports the argument that, given their relative lack of advanced technology resources, technology transfer is essential for developing countries. The main focus of this study thus centres on a series of strategic issues related to the selection of appropriate technologies, the effective learning of foreign advanced technologies, and the accumulation of technological competencies.

This study applies the social shaping of technology approach to technological development strategies in developing countries. It sees complex modern technology as a heterogeneous assemblage of diverse technologies and social elements and therefore capable of being reconfigured in their implementation and use. Transfer of foreign advanced technology into developing countries is a process of unpacking and local shaping of these technologies. There are therefore always choices, albeit within constraints, for developing countries to decide which technologies to adopt as finished solutions and which "black boxes" need to be opened. This opens up a range of strategic options in utilising foreign advanced technologies, e.g. between transferring developed technological systems and adapting them to local conditions, or buying in components and/or design-tools to develop systems locally and configuring them into complex systems matched to local requirements and conditions. The study then discusses the choice of these different strategies and in relation to the existing indigenous technological competencies and/or the long term plans for the accumulation of technological capability of a country.

The idea of national systems for technological innovation (section 2.4.1) has recently received considerable attention in the field of technology studies. The concept revolves around an attempt to identify a nation's structural characteristics and policies and their effects on the rate and success of innovation, and implies a search for the optional conditions for a particular country. However national systems are in a continuous process of flux - in the face of socio-economic and technological change - particularly in relation to developing economies and socialist economies in transition. Because China is undergoing the transformation of its system from the centrally planned to market oriented one, its social institutional structure and policies have been changing extremely rapidly. There is thus little value in seeking to identify a particular "best-practice" national system for China to emulate. This research will instead give more attention to analysing the successive strategies and policies in China and their implementation, together with the steps and outcomes of reforming institutional structures, and relate these to some general features seen to underpin effective innovation. In addition, broader considerations, such as domestic social tensions and international opportunities and pressures are also taken into account.

This research is concerned with policy implications. It evaluates major Chinese government policies which have had effects on technological activities relevant to the case of public switching technologies. These include the import substitution policies to protect domestic industry by providing subsidies to firms, high tariff rates and regulations that served to restrict the import of foreign goods, financial support for indigenous technological projects as well as more open policies designed to attract foreign investment and technology inflow. In particular this study examines the dual technology policy, described as "walking on two legs", which encouraged both the transfer of foreign technology into China and the development of indigenous technology. It discusses the conflict between these policies in the long or short term, the sequence and circumstances for their implementation and their consequences, including the positive and negative side-effects.

As well as highlighting issues for China, this study intends to draw lessons and policy implications of general importance for other developing countries, especially those in transition. However, because of the uniqueness of China's size and its historical inheritance, there may be limits in the extent to which Chinese experiences can be extrapolated elsewhere. In addition, given that this research is based on the particular empirical case of telecommunications switching technology, findings may be rather different from other technologies, (for example, automobiles, chemicals or textiles,) which differ in their technical, social, economic and political features. In particular, the strategic importance of telecommunications and the fact that network integrity must be maintained nationally means that the state is a major player in regulating or actually running the telecommunications system.

Above all China has one fifth of the world's population, about 80 percent peasants, 100 millions living under the poverty line. Its success or failure will have a substantial impact on the political economy, as well as the environment, of the entire world. Although this research is mainly focusing on the public switching technology in telecommunication sector, it at same time provides a general picture of the Chinese economic system, its tradition and current transformation. To developing countries, China's experiment will be an important experience and a source of lessons to draw upon for alternative paths of development. To those in the developed world, China might well be a rising opportunity, as well as a threat. These are not fixed matters, but rather can be altered by the endeavours of the powerful developed world - as illustrated in this study, the key policy change on the public switching market was the response of the Chinese government to international pressures from Western suppliers to open up this market.

1.3 Social, Economic and Political Concerns in Telecommunications

Technologies vary in their social, economic and political characteristics and implications. This research examines telecommunications technology, a technology which has enormous social, economic and political significance.

Telecommunications are a recognised part of the fabric of modern society. The telecommunications industry constitutes a public good and provides the backbone supporting a wide range of industries, and has the potential to create many new service activities. The development of the telecommunications industry is also an important factor in stimulating innovation and research and development (R&D) in a range of related sectors. As it can offer such great technical and economic advantages to industry and society, it has long been a focus of attention of business, government and public debate.

For example, telecommunications services make it possible for information to be shared by people world-wide. Because of its crucial and fundamental role in economic and social development, it has the potential to exacerbate inequalities between individuals or communities simply through people's differential access to the networks. Particularly in developing countries, introducing advanced telecommunications technologies into an existing economic and social context could possibly constitute new and enhance forms of inequality and uneven development between rich and poor, central and peripheral regions, and urban and rural areas. Equally in today's business world, efficient telecommunications services have become so essential that it is one of the most important factors for a developing country to attract foreign investment.

The social and economic significance of telecommunications makes it politically crucial as well. From its earlier years the telecommunications industry has been of great concern to governments in almost all countries, since the days of the electric telegraph. Looking back in history, the state has been drawn to play a variety of roles, e.g. as a customer of the products, a financial sponsor for R&D projects, a guardian and a regulator for the industry and a co-ordinator to initiate product innovation, etc.

Telecommunications services involve three operational areas - transmission, switching and terminals. The first two of these are complex, large scale technologies. Network provision in particular is subject to marked economies of scale. It has been presumed that economies of scale and network "externalities" (the growing benefits with larger numbers linked up to a system) would favour "natural monopoly" of telecommunication provision (which would need to be) run or tightly regulated by the state. Given the huge capital costs of telecommunications networks, especially the "local loop" to individual domestic consumers were presumed to prohibit competitive provision of fixed link phone services. Duplicate provision would be inefficient and too expensive. Public management, through nationalised service or state regulation, could further enable the network to be developed in line with broader social and economic policy objectives - for example to allow equality of access. However the traditional model, whereby the state was the guarantor or monopoly provider of telecommunications services, has recently come under sustained attack, with moves toward privatisation, opening up the sector for competition and so called de-regulation (though this often in fact involves re-regulation of the sector), spreading from the USA to UK, the rest of the European Union, and the rest of the world.

In a context of rapid technological change and the growth and diversification of telecommunications service markets, it has been argued that state regulation or state monopoly provision have proved inefficient because of the lack of competition and have served as an obstacle for further technological innovation. However, some researchers such as Vickers and Yarrow (1996) and Ypsilanti (1988) suggest that privatisation and competitive provision may be not a better solution in the longer term, particularly in the provision of telecommunications network facilities.

Similar arguments have surrounded the supply of telecommunications equipment. Its enormous costs stimulate governments to seek domestic manufacture to improve balance of payments. Strategic considerations have motivated many countries to ensure national ownership or control of production facilities and innovation capabilities of the technologies involved. However, recent advances in switching technologies - the move to electronic switches, and in particular to programmed control and digitisation underpinning PDSS had been associated with a dramatic escalation of research and development costs. This posed particular problems for poorer (e.g. smaller and especially developing) countries which lacked the necessary financial and human resources. The scale of investments required is frequently beyond the capacity of individual domestic companies without assistance from the state or large foreign companies. PDSS posed a strategic challenge for developing countries. They offered greatly reduced costs and scope for rapid expansion and upgrading of telecommunications services. But they also posed a number of dilemmas. The first concerns whether to develop the technology locally or buy it in. In the latter case there were further dilemmas. Strategies of state control (or even nationalisation) of foreign firms which might have been relatively successful in relation to earlier mature generations of electromechanical switching technology might frighten away foreign companies, technologies and investment. Opening up the market for a single foreign supplier might make it more attractive for private firms to accept public requirements (e.g. to keep costs low or allow for domestic production), but might lead to dependency. On the other hand allowing free entry and market competition could produce fragmentation of the telecommunications network and inefficiencies associated with duplication of technologies and incompatibilities between them.

1.4 Context - China's Transition

China has been seeking economic prosperity for generations, no matter whether its government was "republican", "nationalist" or "socialist". However, recent history has not favoured this ancient giant, the "central kingdom". While the West prospered, China, beset by the colonial powers, was subject to sustained political and economic turbulence and chaos (including civil strife and foreign invasions) until the 1949 success of the Chinese communist party. Since then, there have been several periods of rapid economic growth. Under the People's Republic, for the first time after a long period of impoverishment, the country was able to feed its population, by then one billion, and the majority of the population came to believe in the leadership of the country, with the expectation that this government would deliver continued improvements in economic and social well-being.

However, like other socialist states, over time the initial impetus of the revolution gradually eroded, and people's confidence and inspiration faded away. Mao's political campaigns inside and outside the governing Communist Party did not save the socialist system from decline. Mao's policy explicitly prioritised matters of ideology over economic pragmatism. Rather, economic development became tangled up with political movements. Ever-changing policies resulted in fluctuations in economic development and reached its lowest point in the late stages of the Cultural Revolution (1966-1976).

China has been reforming since 1978 when the Third Plenary Session of the 11th Central Committee of the Communist Party of China was held in Beijing to inaugurate China's policies of economic reform and openness to other countries. In a relatively short period China has become one of the countries in the world with the fastest growing economy. Between 1978 and 1993, economic growth averaged nine percent a year. In 1992 and 1993, GDP increased 12.8 percent and 13.4 percent respectively (Li Tieying, 1994: pp.3). China's share of world trade has doubled and 200 million people have been released from absolute poverty (Balls, 1993). "The dynamism of the Chinese economy has been a major factor underlying the rapid growth of the region's trade and output which has contributed to maintaining stability in the world economy"

(UNCTD, 1994: pp.7). Some consider that China will become the world's next economic superpower (Balls, 1993).

Unlike the former Soviet Union and other former socialist states, China is commonly seeking to combine socialism and market mechanisms. The motto of China's transition as defined by the Communist Party is to establish a "socialist market mechanism in a planned economy" and to build up "four modernisations" (upgrading industry, agriculture, national defence and science and technology) with "Chinese characteristics". The term "socialism with 'Chinese characteristics'" reflects the challenge facing China's transition with no existing model to follow, as well as its pragmatism and the importance attached to social prosperity. This pragmatism is an essential element of Chinese culture, embodied also in the Chinese leadership, as captured by Deng Xiaoping's phrase "whether a black cat or a white cat, the one who can catch rats is the best". It is precisely this pragmatic attitude that Chinese reformers and ordinary individuals, are displaying in pursuing the current process of socio-economic transformation. "Chinese socialism" is the product of such a culture.

In China, not many people are seeking a clear definition of what "socialist market economy with Chinese characteristics" means. Instead, since the market economy is new for China, people are learning about it while practising it. After thirty years under a state socialist system, and especially after the previous ten years of the Cultural Revolution, in which people have seen all too many of the errors and defects associated with socialism and a centrally planned system, people have high expectations for a market economy. Only recently have some of the problems endemic to market economies become apparent. These including the widening of economic inequality between individuals and between districts, high inflation, increasing unemployment and disruptive migration from the countryside to the cities and from poor districts to the richer coastal areas. People are now beginning to recall the merits of the previous socialist system.

China's reforms have taken place in three phases. The first phase, from December 1978 to September 1984, mainly concentrated on the agricultural sector. It sought to introduce a more market-oriented system and to give farmers with greater scope for private initiatives. This ended successfully with a "rapid increase in agricultural productivity, a dramatic reduction in the incidence of poverty" (Yenal, 1990: pp.707). From October 1984 to December 1991, the second phase of reform shifted the central focus to urban areas and was mainly directed to reorganise the industrial sector. Government policies sought to stimulate the dynamism of industrial sectors by introducing market forces to the entire system and giving much more autonomy to enterprises. In the third phase, since the beginning of 1992, the sphere of economic reform has broadened in many aspects and the process has been stepped up. The aim is to build up a new socio-economic mechanism for the country (Li Tieying, 1994: pp.7).

A major objective of economic reforms is the promotion of dynamism of the technological innovation system. Progress has been unprecedented as economic reform has led to the integration of economic development with technological innovation. However, in contrast with the other social, political and economic policies, the core of science and technology policies has shown key elements of continuity in the importance it attached to both developing technology locally and introducing advanced technology from abroad.

As early as 1949, with the foundation of the People's Republic of China, one element of the technology policy was described colloquially as "walking on two legs" - that is to say, to combine foreign and national aspects in technology development (Li Wan, 1991). Accordingly, the strategy for the development of science and technology aimed to establish a number of advanced industrial enterprises and to acquire large amounts of modern technology (Li Wan, 1991). There were many ups and downs in technology development before the 1979 economic reforms largely due to political fluctuations as well as to fundamental problems of the socialist centrally planned system (in particular the poor linkages between R&D institutes and production organisations, and the lack of incentives for firms to adopt technological innovations).

In December 1980, National Labour Conference on Science and Technology in Beijing had the explicit objectives of overcoming these problems. In particular it sought to integrate the S&T systems with economic development. The strategic motto was clearly presented that

> "Economic construction should rely on scientific-technological progress and that science and technology has to serve economic construction. It was pointed out that the main task of scientists and technicians was the development of the national economy, and that the majority of the scientific-technological forces should be shifted to the main field of action - to serve the development of the national economy" (Li Wan, 1991: pp38)).

This began the introduction of market mechanisms into the field of science and technology research and development. These new steps were explicitly aimed at catching up with the West and developing new technologies and high technology.

One of the important features of these new technological development strategies is the "open door" policy, addressing "rigorous promotion of technology transfer". Opening China's economy up to other countries was in order to import funds and highly qualified personnel, and assimilate advanced science and technology and experience from abroad (Li Wan, 1991). Under this policy, in the late 1980s, the issue of the introduction of foreign technology came to be seen as all important. Newton's line - "If I can see a little farther, then it is because I am standing on the shoulders of a giant" - was frequently quoted by those who believed that "technology import is more efficient and uses less research personnel than research itself" (Li Wan, 1991: p.44). It was believed that China should not only seize opportunities to import foreign technologies, but also make every effort to assimilate, remould and innovate the imported technology in a so-called a "healthy cycle". (Li Wan, 1991). This concept drew upon Japanese experiences: the "healthy cycle" is considered as a series of spiral developmental activities: import of advanced technology; assimilation; new creation; extension of exports and increased imports (Li Wan, 1991).

The Chinese government has stated that the opening to other countries and rigorous promotion of technology transfer represent a fundamental long term state policy and a strategic measure to accelerate socialist modernisation. However, the what really matters are the changes actually taking place in China's technological innovation systems and its benefits to the economic development, (as well as any problems which may arise and lead to policy shifts).

Today China is undergoing a socio-institutional transition. The whole system is characterised by instability, as well as by an acute shortage of almost everything. Like other developing countries, China has been short of capital and natural resources in proportion to its population size, the rapid rate of population growth and the slow rate of capital accumulation (Mu Gongqian, 1991). In these circumstances, the behaviour of institutions like individual enterprises or firms, local government organisations, sectors, and even the State, is largely determined by the immediate external and internal opportunities and pressures bearing upon them. In these contexts, their scope for developing and implementing new policies are highly limited.

China is determined to catch up in economic development. Especially, since the economic reforms, its impressive success is reflected in rapid economic growth. As a former socialist state, China has chosen a way of development rather different from the former Soviet Union and many other countries in the Eastern Block - a strategy that combines socialism and the market economy. The Chinese government policies in technology development pursue dual development: on the one hand, rigorously importing foreign advanced technologies and, on the other, encouraging assimilation and innovation of imported technologies. But, in reality, China is facing enormous constraints and problems in its road of seeking for social prosperity. Old problems stemming from the socialist system are still there while new problems associated with the emerging market-oriented mechanism have surfaced.

1.5 Outline of Thesis

There are three parts to this thesis. Part I, the background to the study consists of three chapters. Chapter 1 outlined the scope and intellectual underpinnings of the study, flagges the importance of telecommunications technology and describes the context of China's political and economic situation. In Chapter 2, the literature in three areas - development studies, the study of socialist economics and transition and technology studies - is reviewed and discussed. These form the basis of my theoretical framework. Basic concepts important to the main themes of this study are defined. Finally within this theoretical framework, the presumptions and research questions are brought forward for examination in the rest of the thesis. Chapter 3 describes the research design and methodology of this study, including the process of fieldwork.

Part II presents the empirical findings - focusing on two case studies, in which the innovation processes in the development of two public switching technologies, one indigenous and the other foreign, are explored. To set the scope for these, Chapter 4 first depicts the historical background of the Chinese telecommunications infrastructure, the Ministry of Posts and Telecommunications, PDSS technologies and industry. It is then followed by two major chapters giving detailed accounts of the case studies. Chapter 5 explores the case of import of a foreign PDSS technology, specifically the process of technology transfer of System 12. It examines the process of technological innovation (adaptation and improvement) and changes in the social and economic arrangement (e.g. related government policies) over this period. The acquisition of technological capability is investigated with the analysis of the joint production venture, Shanghai Bell. Chapter 6 examines the case of the indigenous technology, detailing the process of building up the sociotechnical constituency for the Chinese public digital switching system, HJD-04. This involves three players: a military research institute which initiated the project, a state-owned firm which produces the HJD-04 system, and a governmental organisation, the Posts and Telecommunications Industrial Corporation. Along with elucidating how social factors in the transition shaped technical features of this technology, and how technical and organisational elements were aligned together, it gives a close-up examination of the state-owned firm, its accumulation of technological capabilities, problems encountered and progress made.

Part III is concerned with analysis and conclusions and has three chapters. Chapter 7 analyses the process of PDSS technology development and the range of strategies revealed by these cases by the comparison between indigenous and exogenous technology acquisition processes encountered in the case studies. Chapter 8 evaluates contributions of the broader social and economic context to PDSS technology development in China's economic transition. Finally, Chapter 9 presentsthe summary and conclusions of this study.

Chapter 2.

Theoretical Framework

2.1 Introduction

This chapter explores the possible contributions to this study of writings from three disciplines: development studies, writings on socialist economics and technology studies. This provides the basis for the theoretical framework for my research. As the fields reviewed are each extensive, it has been necessary to be selective in this account of the literature and main debates. The sources used, and the framework presented here, reflect the particular concerns and values which have underpinned my research. In this complex area it is possible that different people could arrive at rather different interpretations, even of the same historical phenomena, insofar as they draw upon their own knowledge and belief systems which, in turn, are built upon their past experiences and early knowledge frame. Thus, it is not possible to create a single authoritative account. This is why it is interesting and useful in social sciences for various researchers to address the same subject.

Section 2.2, "Modernisation, Dependency and Intermediate Technology", is the review of development studies, and in particular of the issues relating to technological development and its relationship with economic development in developing countries. From the vast range of theoretical writings on socialism, section 2.3, "The Implications of Socialist Practices", focuses upon debates about the role of markets and state within socialist economies. Section 2.4, "Technology Studies", examines the range of relevant approaches within technology studies and their relevance to this study.

Section 2.5 summarises the rationales as an outcome of literature review and draws threads between the theoretical framework of this study and research questions to discuss throughout the concrete cases in the rest of these chapters.

2.2 Development Studies

The systematic study of the problems of development in developing countries (DCs) has emerged mainly in the period since World War II. Amongst many theoretical approaches in literature on development studies, economic development in DCs has been a central focus, and similarly economic theories are the main stream of the field. A dominant tradition, associated with modernisation theory, suggested that developing countries should simply repeat the industrialisation process of the advanced economies. However, the largely frustrating experiences of developing countries in the 1960s and 1970s (especially in Latin America and Sub-Saharan Africa), and comparatively successful more recent experiences of the newly industrialised countries (NICs), have challenged these classical economic perspectives and opened new territories for development studies. Today, it has been by and large acknowledged that development is not purely an economic phenomenon, rather a multidimensional process involving the reorganisation and reorientation of entire social as well as economic systems. In particular, technological development has come to play an increasingly important role in the economic and social life of developed and developing countries.

Section 2.2.1 discusses lessons this study can draw from post-war literature on development studies, distinguishing three main intellectual traditions: modernisation theory, dependency theory and the approach of intermediate technology. Section 2.2.2 highlights the importance of the recent practical successes of the newly industrialised countries and discusses the issues that this new phenomenon throws up for development studies and the strategies of developing countries.

2.2.1 Modernisation, Dependency and Intermediate Technology

There are many theoretical approaches within the post-war literature on development studies. A variety of schema have been proposed to categorise these diverse approaches. These include, for example, the mainstream modernisation theorists, structuralist approaches and dependency theories. Various writers reviewing this field have sought to synthesise and categorise this diverse literature (Clark, 1985; Colman & Nixson, 1994; Chenery and Srinivasan, 1988; Dutt & Jameson, 1992; Hirschman, 1981; Taylor, 1992; Todaro, 1994; Smith, 1995). However, scholars from different academic, social and political backgrounds have treated theoretical concepts differently, or given different emphasis to particular elements, and have thus arrived at different classifications of the main theoretical trends and the relationships between them (Smith, in Pillai & Shannon 1995, in particular section 1). For example, in many accounts the 'structuralists' are attached to dependency school, however, in some other schema, structural-change theories are associated with those, such as Lewis, Chenery and some post-Keynesians (Todaro, 1994), who are broadly associated with the stage-model that derives from modernisationist accounts. These differences are not "just academic" but reflect sharp political differences within the field of development studies. Thus there have been controversies about the contribution of various traditions. For example, modernisation theory has been strongly criticised on the grounds of its implicit ideological support for neo-colonialism or imperialism (Barratt Brown, 1974; Leys, 1975, 1977; Smith, in Pillai & Shannon 1995; Warren, 1980; Cardoso & Faletto, 1979). However, others have seen modernisationists as making an important contribution to the theoretical development of development studies, linking them to those of developmentalists who were ambitiously seeking a unified model of development (Smith, in Pillai & Shannon 1995).

Despite these differences of view, modernisation theories and dependency theories are more or less consistently recognised by most scholars as representing two contrasting views in development studies. Whilst the former was articulated largely by scholars from the industrialised countries, the latter emerged from DCs countries (notably based on experiences in Latin America). It would probably be too simplistic to say that these two theories have been the mainstreams in development studies. However, they do often represent points in a spectrum, which provide a useful point of entry into the area of technology studies, its ideological, theoretical, and empirical diversity, and the range of controversies that have arisen. Another reason that it is worth reviewing them is that the core of these two perspectives still retain their influence over development studies today (although not many still acknowledge this contribution). Moreover, some of the issues raised in these two perspectives are still relevant to today's practice in DCs.

The most outspoken and influential theory in the Modernisation tradition can be traced to Rostow's stages of economic growth (Todaro 1994). Rostow, as an economic historian, classifies all societies into five stages: the traditional society, the pre take-off stage, the take-off stage, the drive to maturity stage, and the age of high mass consumption. According to Rostovian or modernisationists, all countries pass through the same set of historical stages in the same sequence, and if there are slight variations in terms of timing, duration and other factors, these do not detract from the main process. Less developed countries are backward in terms of their cultures, political systems, social institutions and economic resources. As a result, modernisationists believed that, as an extension of the already developed part of the world, what less developed countries must do is "to compress an essentially linear process into the shortest possible time-scale" (Clark, 1985: p165). "The way to become "less backward" is to borrow, buy or copy those corresponding features of the rich countries felt to be instrumental in bringing about economic growth" (Clark, 1985: p167).

Modernisation theories came under attack from many scholars not only for their economic implications but also on empirical, ideological and methodological grounds. The most eminent critique came from a range of writers from Latin America who developed theories of "structural underdevelopment", which have also been described as "dependency theories" (Santos, 1973). From this perspective, the conditions in the less developed countries were examined as part of a broader international picture. "Underdevelopment is seen as being caused by the dominant influence exercised by developed capitalist countries as a result of certain political and economic institutions which lock poor LDCs into a dependent relationship" (Colman and Nixson, 1994: p29).

Perhaps the heaviest criticism was derived from empirical studies in the third world which showed that the Western model of development had brought negative consequences including unemployment, dependency and disequilibrium. Latin American and African countries are seen as typical victims of this development approach. And the Western model of development was condemned as "maldevelopment" or "distorted development" (Goulet, 1983). It was believed that, even where high economic growth had been achieved, mass misery still continued. There, a small portion of people gained wealth through economic growth. However the majority was by-passed, and these benefits did not trickle down to the poor masses.

Dependency theories have a very pessimistic view of the prospects for technology transfer, let alone the acquisition of technological capabilities by developing countries. With regard to technology transfer, it is believed that the ownership or control over advanced technologies is not transferred, and there is merely a geographical movement of technology from one set of geographical boundaries to another, but still within the control of the metropolitan economy. Thus developing countries do not have effective access to the whole range of existing technologies, and the price structure is always based on the seller's market. Moreover, Western technology is regarded as a two-edged sword, simultaneously creating and destroying different kinds of values-destroying old values and uprooting people in alienating fashion, and threatening indigenous values, local economies or local institutions in developing countries (Goulet, 1983). Indigenous technological competencies are even less possible to achieve, as developing countries are considered to be poor and lacking technological resources, not only equipment but also know-how and manpower. Therefore, the more a developing country relies on advanced Western technologies, the more it will reinforce its dependency on industrialised countries.

Some of the most radical critiques have led to extremely pessimistic views, based on notions of "a series of interlocking vicious circles of poverty and stagnation", "backwash effects", "low level equilibrium traps", "backward sloping supply curves of effort" and the like, which assert the impossibility of economic development in less developed countries (Clark, 1985). Some even concluded that "stopping economic growth would be the solution" (Riedijk, 1982: p2). However, these dependency theories have been subject to increasingly severe criticism (Lall, 1975; Lays, 1977; Palma, 1978; Warren, 1980).

For the purpose of this study, it is not necessary to review all the writings within these two perspectives. Instead, I will draw out those aspects which are most relevant to the theoretical framework of my research. As we have seen, the core theory of modernisationist perspective, the linear-stage model of development, has hardly any credibility in development studies today. However, its implicit presumptions have become deeply rooted in much contemporary thinking about development. Let us leave aside for the moment two long-standing criticisms of modernisation theories - first, that politically and ideologically they reflect colonialist and imperialist views, and, second, that their schematic form does not provide a useful framework for critical analysis nor for policy prescription. However, we can still acknowledge the usefulness of a range of detailed empirical studies conducted within this framework. For example, modernisation theories generalised the features of experiences of economic and technology development in the West, in particular, the powerful integration of technology and market economy. This point is closely related to the interests of this research, and I will explore it in detail below.

The "dependency" or "structural underdevelopment" theories opened new perspectives for developing countries to understand their situation within the world-wide economy and the sphere of international politics. This structural perspective is obviously useful for comprehensive analysis of the technological, social and economical development in developing countries. However, from the early 1970s onwards, dependency theories came under increasing criticism on both theoretical and practical grounds. The latter, in particular, was in response to the success of NICs in which sustained and rapid economic growth has taken place with the state playing a strategic role. Dependency theories could not provide adequate explanation of this. (I will return to this in the following section).

Despite this, it is undoubtedly the case that dependency theory has provided many important insights into the characteristics of developing countries and the interaction between them and developed capitalist economies. For example, one of the important contributions of dependency theory is to show that the problems of development are not only a question of economic growth, but that the broader social dimensions must be addressed. It highlights a range of social issues in developing countries, including social security systems, unemployment, income distribution, poverty. Technological change, and especially the negative consequences of technology transfer from industrialised countries, are given particular attention. Moreover, these negative consequences identified by dependency theories as arising from economic growth in developing countries on Western lines are still arising today: continuing unemployment with excessive immigration from rural to urban areas is causing serious social instability; the gap between rich and poor is widening; and pollution of natural environment and excessive exploitation of irrenewable resources are worsening. On top of these difficulties are added also the effects of the discriminatory trade barriers imposed by industrialised countries. "Textiles are the most obvious, though not the only, example" (The South Commission, 1990: p29).The DCs have been playing a role in providing low-price food and raw materials to industrialised economies, in order to buy highly value-added industrial goods as well as technologies.

The critique advanced by dependency theory has been one factor stimulating the emergence of an important concept about technological development in developing countries. This is 'intermediate technology' (or appropriate technology), which points to an alternative development approach that seeks to encourage self-sustained growth through the design and development of technologies that build upon locally available skills and resources, and appropriate to the local, social and cultural circumstances. A leading role in espousing this concept has been played by Schumacher's publication, "Small is Beautiful" (Schumacher, 1973). Various bodies, such as the Intermediate Technology Development Group, which was established in London in the late 1960s, have sought to put these ideas into practical application.

Like dependency writers, Schumacher and his supporters attributed many disastrous manifestations in the world to modern technologies. They concluded that:

1) many Western technologies are inappropriate to local conditions in developing countries;
2) there is a huge imbalance in technology trade between richer and poorer countries;
3) technology transfer has reinforced dependencies of all kinds; and
4) the values of less developed countries' are being manipulated and people are being mobilised to support goals reimposed from the external - metropolitan economies of industrialised countries (Schumacher, 1973).

To counter these tendencies, they therefore called for alternative development approaches. Intermediate technology is supposed to be appropriate for local conditions in less developed countries and regions, and to meet certain criteria, e.g. being easy to access, easy to learn, and being suitable for small scale regional or district production with local resource supplies (Schumacher, 1973).

The intermediate technology approach appears to provide a very promising model of technological development in developing countries, by encouraging indigenous technological capabilities. However it has obvious weaknesses. First of all, the ideas about which technologies might be appropriate have been confined to a very limited category of artefacts and technologies - which effectively rules out a wide range of existing technologies, particularly advanced technologies. Second, the practical achievements of appropriate technology have been very limited. This draws attention to weaknesses in its theoretical framework - and in particular its treatment of technology. Schumacher and his supporters only recognised the fact that technology embodies social factors of the country which developed the technology. But they did not pay sufficient attention to the possibility that exogenous technologies could be sufficiently flexible to be useful in a wider range of circumstances or could be adapted to the particular local context of developing countries. Further, they have largely confined their search for technologies appropriate to developing countries to a series of relatively inefficient traditional technologies, to the exclusion of modern technologies which are often extremely resource efficient (Beckerman, 1995).

One of the reasons for these theoretical and practical shortcomings can be linked to shortcomings in Schumacher's conceptualisation of technology. Schumacher saw socio-economic values as becoming embodied in technological artefacts - that were conceived as stabilised "black boxes". Their implementation and use would therefore impose certain socio-economic arrangements and outcomes. In this respect, Schumacher's perspective on technology can be seen to have incorporated some features of the "technological determinist" approaches (Williams and Edge, 1992) which were extremely prevalent when he was writing. From this perspective, therefore, technology transfer tends to be virtually treated as the synonym of technology transport from one place to another. I will return to this point in section 2.4.

2.2.2 The Challenge of the Newly Industrialised Countries - NICs

A key feature of the global economy in the last decades has been the marked process of economic and technological development in a number of peripheral economies - the so-called newly industrialised countries, notably Hong Kong, Singapore, South Korea and Taiwan. These experiences present a sharp challenge to existing theories and models of development studies. The high growth rates experienced by East Asian NICs obviously contradict the pessimistic conclusion assumed by advocates of dependency. On the other hand, it is fairly clear that the model of development under way in the NICs is far removed from the modernisation theorists' concepts, discussed above, to create DCs in the image of the social order now present in the developed countries (or the concept that DCs had to replicate their particular development paths and methods, e.g. laissez-faire system and industrialisation). The NICs' success has attracted the attention of scholars from a variety of tendencies - whether modernisationists, dependency advocates, neo-Marxians, structuralists or other neo-classical economists (Dutt, Kim and Singh 1994). It has stimulate detailed investigation of the NICs' practices across a broad range of dimensions (e.g. institutional structure, government policies).

The interpretations drawn from the NICs' experiences are often highly controversial. The theoretical approaches of individual scholars tend to lead them to reach different conclusions. For instance, neo-classical economists see their laissez-faire model in the successes of Taiwan, South Korea, Hong Kong and Singapore (Wolf 1990); others attribute this to the role of government intervention (Amsden 1989, Wade 1990, Singh 1992). However, some conclusions are now becoming commonly acknowledged (though intellectual debates are continuing and inducing further research on the details of The NICs' experiences).

First, it is commonly recognised that governments in Taiwan, South Korea and Singapore have played substantial role in provision of macroeconomic policies and infrastructure, such as directing capital investment and technological development, issuing restrictions on imports for industrial promotion, etc. The market is guided by the long term national plans for investment and industrial development formulated by government officials; the content and pace of industrialisation is not left entirely to the aggregate decisions of individual businessmen (White & Wade 1988). The extent of government intervention at the industry level varies according to perceived necessity. Some industries have accordingly been highly subsidised and directed by the government; others have experienced policy intervention only intermittently; the rest have been more or less left to take care of themselves within a broad framework of regulation (Wade 1985, Pack and Westphal 1986, Bardhan 1988). One of the main areas of debate among different schools of thought within development studies concerns whether these interventions played a positive role in economic development in these countries. When we compare the development experiences of these NICs with those in economies subject to strict state control across the board, and those at the other extreme that have relied upon laissez-faire approaches, what emerges as an important feature of the countries is not their resort to state intervention or market forces, but the way they manage to blend market force and government intervention in an appropriate manner.

Second, East Asian NICs attach considerable importance, in economic development, to the accumulation of technological capabilities. In contrast to the predictions of dependency theories, Singapore, South Korea, Hong Kong and Taiwan have obtained technological competencies in such areas as consumer electronics, semi-conductors along with a range of manufacturing technologies in traditional industrial sectors. Moreover, in this process, The NICs' experiences show the feasibility and indeed necessity for dual technological development, transferring advanced technologies from developed countries on the one hand and facilitating the adaptation of foreign technologies into local conditions on the other. Considerable interest has been shown in the influence that selective technology acquisition strategies might have effects upon the prospects for technological dynamism and industrialisation of DCs. Attention has become concentrated recently on investigations into the actual and likely impact of the "radical" new technologies associated with the use of the microprocessor in many branches of economic production and distribution (Luedde-Neurath, 1988).

Third, the success of NICs invites detailed research on the contribution to technology dynamism of national institutional structure and strategies (and how these have changed over time). In these countries, industrial policies of import substitution and export orientation are not contradictory; both have been applied in the process of industrialisation. It is commonly recognised that South Korea, Singapore and Taiwan began their industrialisation drives with high levels of protectionism, and gradually became more export-oriented (White and Wade, 1988). This raises a range of research and policy questions, concerning the extent to which national strategies are applied across different sectors and at different stages in the process; when and how to apply these strategies; how these strategies are implemented and technology dynamics are achieved.

Finally, an important observation from the studies of the NICs' development experiences concerns the uniqueness of development process in individual countries, reflecting their specific historical characteristics in terms of cultural, economic and political development. The international environment in which a development process takes place is relevant too. In spite of the encouraging aspects derived from the success of NICs, many have suggested that the transferability of their experiences is extremely limited.

In summary, NICs' experiences greatly challenged the intellectual traditions of development studies. This also shift the central focuses of development studies from more generalised issues on to more specific ones, such as the role of state and government policies on industrialisation, foreign trades, science and technology development strategies, etc.; accumulation of technological capabilities; and technological dynamism. More importantly, this new shift provided much prospects of technology and economic development to developing countries, especially those in Asian Pacific region. For China, it is extremely tempting to try to follow the suit in achieving technological development and economic growth, and the reform of the socialist central planning system has become the pressing undertaking. Next section will turn to recent writings on socialist economics relevant mainly to China's socialist practices.

2.3 The Implications of Socialist Practices

This section aims to clarify my standpoint about the problems facing socialist societies particular in relation to economic and technological development through a review of recent writings on socialist theory. The collapse of the political and economic systems in the Soviet Union and the Warsaw Pact countries, and the challenge of resurgent new liberal policies to Western forms of social democracy has thrown traditional concepts of socialism into a deep crisis. Many writers on the left have been forced to reassess their approaches. Some of the fiercest controversies have arisen between writers in the Marxist tradition, involving sharp polemics about the nature and definition of socialism. However, I have only limited interest in these theoretical, and often sectarian, debates. Instead, this review focuses on the practical issues which socialist states like China are facing and particularly those arising with their transition.

My main concern here is pragmatic - to build up a framework which will provide a means for socialist developing countries and to achieve economic and technological development in the context of transition, rather than digging to find out authentic socialist theory. In particular, based on the analysis of socialist practices in the past, it emphasises the need for diversity of applying state interventions apart from the central planning and direct state control, and the importance of using these instruments strategically for technological and economic development. Section 2.3.1 discusses selectively the issues put forward by the current crisis of socialism in both theory and practice, concerning the transition of former socialist states from centrally planned to market oriented economies, and through this process brings out the rationale on which my position is based. Section 2.3.2, from the view point of technological development, goes further to examine the problems or merits of "socialist traditions" - and in particular of the state control and central planning.

2.3.1 The Central Planning System

Contrary to the expectations of 19th century Marxists, 20th century socialist revolutions had taken place in largely pre-industrial or industrialising countries. It is generally acknowledged that the early socialist regimes in Russia and China alike made great achievements in industrialisation.

Taking China as an example, the socialist government achieved, in the first five years after revolution, 18 percent increase per year on average in industrial production and a 4.5 percent average growth in agricultural production. People's living standards rose substantially, with average wages of the non-agricultural labour rising 42 percent and of peasants 27.9 percent in this period (Zhou 1982). The regime had the strength and stability to fend off external pressures and destabilisation. Similarly, the Soviet Union proved more efficient than many of its capitalist counterparts in achieving rapid industrialisation in an industrially backward country through high rates of saving and concentrated investment as well as in building national economic independence and national security (Stauber, 1987).

However, the initial dynamism which followed the transformation of these semi-feudal and chaotic societies was not sustained. The central state planning system, which seemed so effective in developing large-scale basic industries and providing essential social needs of food, clean water and housing, seemed less well suited for producing non-essential consumer products that populations sought as their living standards rose. Leftwich (1992) comments that socialist states have been facing systematic constraints associated with the centralised planning system. They need to achieve international competitiveness, develop alternative planning and management systems capable of dealing with complex resources flows which characterise more developed economies, and meet popular demands associated with non-essential consumption - for consumer durables, improved housing, better quality and variety of food, etc.

White (1988) has examined these problems in the case of China. Within this system of planned state industry, relations between state economic organs and industrial enterprises, and among enterprises themselves, are not based on commodity exchange regulated by the "law of value" through the markets, but are subject to unified co-ordination and control at various levels of the state planning network. The pattern of industrial output is predominantly determined by state officials not market demand; production functions are set by the plan according to relatively unchanging, standardised technical coefficients; most prices are regulated administratively and are only marginally subject to pressures of supply and demand; money plays a passive, accounting role, monitored closely by a centralised banking system with cash playing only a marginal role; industrial manpower is administratively allocated by state labour bureaux; inter-sectoral product flows are determined by a balancing process based on physical input-output ratios; supplies of raw material to industrial enterprises and purchase of their products are both handled administratively by specialised state agencies. Under such a system, although firms are formally independent accounting units responsible for calculating their own profits and losses, in reality they are administratively subordinate, responsible for carrying out the planned targets issued by superior state organs. White concludes that, "Just as capitalist enterprises in competitive conditions are theoretically 'price-takers', so socialist enterprises in such centralised conditions are theoretically 'plan-takers'" (White 1988: p155).

These criticisms of the problems of socialist planned economies have now been well rehearsed with a substantial recent contribution by writers from the former socialist states (e.g. Brus & Laski 1989, Kornia 1986, Zhou 1982 and more other Chinese economists).

Studies of socialist countries show that the information on which central planning is based is always inadequate and that the state machine is too large and rigid to react to a situation that is continually changing at various levels, including consumers' demand, requirements of firms and institutions in the supply chain, and a changing external context (e.g. of global technologies and world trade) (Brus & Laski 1989). As described by Brus and Laski (1989), the "inconsistent plans cannot be fulfilled in their totality by definition", let alone the "unforeseeable reactions of the economic actors to unexpected events which must be included" (ibid.: p42). The informational weaknesses of the system interact with weakness of incentives: the lack of competitive incentives and the fragility of those linked to consumers' choice (Brus & Laski 1989: p44).

The lack of incentives for change within an essentially static system is the other fatal problem. The socialist incentive system relies on people's inspiration, government mandate and officially organised competitions (Zaleski and Wienert, 1980), which are in reality often unreliable. Because people had life-long tenure of employment within organisations, their sense of motivation, based upon general inspiration for socialist construction, gradually become eroded. The incentives for hard work and better performance gradually declined and could only be sustained at a low level. Moreover, labour allocation was conducted by the state, and human mobility was limited. Government agents at various levels of the state planning network became bureaucratic organisations and were not able to play active role in monitoring and promoting technological development.

2.3.2 The Systems of Rigidity

The lack of technological dynamism has come to be seen as an increasingly critical problem of state socialism. It stems from the lack of integration between the research system (specialised R&D institutes) and industrial organisations, and the weak links between technology designers and producers and technology users. R&D institutions were by and large separated from industries, and manufacturing firms were separated from product users. In the main, government agencies were not able to play an active role. Information exchange between players was inadequate, apart from the rather crude requirements of central planning. Therefore, the bigger the system, the more rigid the system was for technological changes.

R&D institutions themselves have little interest in understanding what industries need, since their finances are provided by the state, and R&D projects are not selected according to the demand of industries (Balàzs, Faulkner and Schimank, 1995a). Similarly, industries have no need to co-operate with R&D institutions, because most technologies are freely provided by the state. Firms find their output targets set on a continuing "ratchet principle" that impels them to seek increased output without concern for cost, quality or customer satisfaction. So, although they are the "carriers of innovation" they have little space to improve their performance. In turn, customers only had limited scope to impose their requirements because of the supply-driven system. They found that they had little option except to accept what was produced.

All these factors resulted in low productivity, and a waste of technological resources. Worse, firms - the supposed carriers of technological change - and other relevant institutions lack motivation to improve this situation. Although the socialist system is supposed in theory to promote technological development by controlling science and technology to ensure free education of people and technology exchange by any enterprises (Bhalla 1992), in practice it failed to deliver the expected results. Apparently, central planning without market forces is not able to provide necessary and adequate incentives for technological development.

2.3.3 State Interventions versus Markets

An important current in socialist, and in particular Marxist, thinking has seen markets as incompatible with socialism. This perspective has been reflected in government policies, at different stages in the history of state socialist countries, to suppress the operation of market forces, for example by insulating the national economy from the global economy.

Authors like Ticktin, Bettelheim, Sweezy, McNally and Elson, and many from a Trotskyite or Maoist persuasion, all argue that markets and socialism are incompatible. Bettelheim and Sweezy insist that there is a viable socialist economic model without involving the market (Bettelheim, 1970). However, McNally admits that the market can not be eliminated overnight and would have to play some role for a considerable period of time in the transition to socialism (McNally, 1993).

In contrast, Leland Stauber (1987) notes that,

> "After all, there have always been market elements in such examples of central planning as that of the Soviet Union even in its most centralised periods, and there have always been considerable elements of government intervention even in the most laissez-faire era of nineteenth century capitalism" (Stauber 1987: p338).

Stauber also looks at the features of Western capitalism, and explores the implications and problems of a broader form of socialism drawn upon the practical experiences of socialism within Western capitalist economies. Based on the analysis of modern capitalist economies in the United States and Western Europe, he sees the problem of the "simple dichotomy" in which "on one side of the fence lies the combination of private ownership of business corporations with an emphasis on the market and decentralisation to the level of firm", and "on the other side of fence lies the combination of the principle of public ownership with a large amount of government economic planning and hence a large amount of government control required to implement such planning" (Stauber 1987: p321).

Stauber further points out that contemporary Western Europe displays existing practices that do not fit the ideologies either of capitalism or traditional socialism, but which exhibit many considerable elements of market socialism (Stauber 1987: p341-342). In his view, the term "market socialism" can be used to denote any of a wide range of institutions and policies that emphasise simultaneously the market within the decision-making process and public or social ownership within the property system along with tax policies designed to eliminate and prevent large private fortunes (p339). A range of types of market socialism can be conceived, extending from only modest departures from the most centralised of central planning systems, at one end, all the way to a situation in which corporate business firms are publicly owned but where their control is structured so that their management operate with a degree of freedom and autonomy no different whatever from that typical of privately owned corporations in contemporary capitalist systems (p338).

Such concepts of market socialism bear obvious similarities to Western social democracies, particularly the more egalitarian participating system such as in Scandinavia. These observations undermine the traditional dichotomy that has been drawn between socialism and capitalism.

Ticktin (1992) points out that modern capitalism is no longer the classical capitalist system based on the free-market. Therefore, for a former socialist state like USSR to introduce the free market system is an example of "reactory utopia", which will not work in the present system of the world. Ticktin refers to the changes in Western economic system as "capitalist decline" or "the breakdown of capitalism". He points out that in modern capitalist countries, governments are playing a substantial role in the economy, intervening via interest rates, subsidies, taxation, etc., and controlling prices and production by large firms. In reality, "the law of value, or the market, is greatly limited in operation" (Ticktin, 1992).

The economic and political collapse of the Soviet Union and its Warsaw Pact Allies has led to an acute debate about the feasibility of socialism, and in particular about centralised state planning. Apart from orthodox Marxism, there is a consensus that ideas of socialism must be reformulated (Qadir and Gills, 1992).

A quite few scholars from a socialist perspective have turned to the solution of the market, although there are significant and important differences in their basic beliefs. Authors like Alec Nove, Geoff Hodgson, Wlodzimierz Brus and Kazimierz Laski, attempt to reconcile socialism with the market (Mcnally, 1993). The influential text by Alec Nove in his "The Economics of Feasible Socialism", (1983) illustrates a model that combines these two. Investment and the infrastructure, in general, would be planned by the state. Health and education would continue to be non market parts of the economy. So-called natural monopolies, such as utilities industries, would remain with the state. For the rest there would be an operating market. For instance, services and consumer goods would be in a market situation. Accordingly, they would set their own prices and conclude their own contracts, which would be based on profit and loss. Meanwhile, the centre (the state) would have a number of vital functions, such as major investment, monitoring decentralised investment directly or through the banking system, playing a major role in administering "naturally" centrally-planned productive activities, while setting the ground-rules for the autonomous and free sectors, with reserve powers of intervention when necessary, and operating the functions connected with foreign trade (Nove, 1994).

Brus and Laski (1989), on the basis of their past experiences in Poland, are more aware of the problems that may arise in the process of realising market socialism, although they "do not refrain from taking sides" (p152). Unlike those who adhere to the Marxist definition of socialism, Brus and Laski admit "there is little doubt" in their minds "that the distinctions between capitalist and socialism, as hitherto perceived, become under MS [market socialism] thoroughly blurred" (p151). They point out that "while advanced capitalism fails to display the expected propensity to transform itself into socialism, the more 'real socialism' matures the more it is compelled to borrow from the capitalist armoury" (Brus and Laski 1989: p151). This brings us to look at the options facing the state socialist countries in transition.

2.3.3 Transition

As a specific model of national socio-economic and political system, the Soviet model, has been demolished. Beyond this, we can find different reactions, given the diverse theoretical approaches and presumptions of the various school of thought, and differences between the former socialist states. Clapham (1992) refers to the demise of "statist orthodoxy" whether in its socialist or capitalist / Keynesian variants, and the concomitant ascendance of "a newly dominant orthodoxy [which] emphasises the need for market incentives, and sees incorporation into the capitalist world economy as the essential motor for growth". He believes that this restructuring affects not only socialist states, but also "actually existing capitalism" (Clapham 1992: p9).

Some view the successes or crises of socialism as a product of the economy and politics of the world. As Shahis Qadir and Barry Gills (1992) indicate, the crisis of penury in the Third World is an integral element of a much broader and deeper economic crisis in the global political economy and a process of restructuring that affects all states, developed and less developed, "capitalist" as well as "socialist" (p9). Colburn and Rahmato (1992) argue that no [developing] country succeeded entirely in breaking out of the capitalist dominated world economic order and constructing an "independent economy". For all, there is no escaping the dependence on generating export earnings, i.e. participating in world trade in order to earn foreign exchange (p10).

In practice, there has been a sharp turn from central planning towards capitalism in most of former socialist states in Soviet Union and Eastern Europe. This has to date resulted in a decline in living standards for the majority of people and a sharp rise in unemployment. The R&D system has also been hit by the deep economic crisis (Balàzs, Faulkner and Schimank, 1995b). Though there are differences, to date most of these states have experienced neither an economic boom nor politically democratic forms. Other less developed socialist states, like China and Vietnam with economic systems that differ from the Soviet model, have shifted to a more pragmatic stance and committed themselves to economic reforms, while ideologically still hanging onto the socialism. In these countries, while encouraging private establishment, major production means remain under public ownership; "marketisation" is conducted gradually within a regulatory framework provided by the state and key industrial and agricultural products stay largely under state control (Jeffries, 1993).

In my view, the overwhelming controversies that surround almost every aspect of "socialism" could only suggest that "socialism" needs reform in both theory and practice. In this case, seeking for perfect and/or complete socialist theories is obviously not very helpful for pragmatic uses in the transition of socialist states.

Perhaps, the most useful things are the understanding of the problems of socialist system, as noted above, which has been gained from the frustrating experiences of socialist states in the past. Notwithstanding this, throughout the history of development of capitalist society in the world, there has been widespread support for socialist ideas which look to the state to combat mass poverty, to protect the interests of the public, and achieve a more egalitarian rather than polarised society.

After the second World War, a large number of developing countries turned to socialism. In the developed capitalist world, collectivist policies such as state intervention to create a substantial public sector, policies and regulations to reduce unemployment and to redistribute private wealth, as well as the development of a social welfare system, have been extensively used in many Western European countries. For example, the Swedish model of "welfare capitalism" (so called for largely nostalgic reasons by both socialists and capitalists), before its crisis of 1991, was actually admired by people in China and regarded as more socialist than that of socialist countries. In newly industrialised countries like Japan, Singapore and South

Korea, the state has played a prominent role in their successful process of industrialisation, as discussed in the previous section.

These may bring us to the conclusion that the current crisis of socialism in both the socialist and industrialised capitalist world does not necessarily suggest the demise of socialism. On the contrary, the transition of socialist states and reformation of socialist theories can be seen as a step in the evolution of our understanding of socialism or in particular advanced socialism. At the same time, the modern capitalist system is no longer the original one, and capitalism which retains "an extensive repertoire of socialist rhetoric" can be regarded as "advanced capitalism" (Clapham, 1992). State control and central planning neither deserve to be discarded, rather they should be thoroughly assessed. If we break the "dichotomy" (see Stauber above), there is no need for socialist states not to use any effective means such as market mechanism in social and economic development. For the same reason, state control does not need to be confined to merely central planning, and central provision of public goods. Practices in Western capitalist countries have shown that governments have many instruments of influence over firms, regardless of whether they are publicly or privately owned. These instruments include both regulatory controls and positive financial inducements, e.g. subsidising, indicative planning with its co-ordination of investment decisions, promoting consultation and etc. (Stauber, 1987).

There is a particular importance for socialist developing countries to use the state and central planning as an instrument to effectively use limited resources, secure social stability and uphold embryonic industries and less experienced firms in participating the world trade, as no (developing) country can succeed entirely in breaking out of the capitalist dominated world economic order and constructing an "independent economy" (Colburn and Rahmato above). At the same time, history has shown that the market oriented economy can give rise to serious social problems, as discussed above, e.g. mass unemployment, large-scale bankruptcies, polarisation of the wealth of people, social instabilities, etc.

Governments have played an important role in the success of the NICs' experiences. Many argued that the modern notion of development rests on a concept of the state as the main generator of socio-economic progress (Hodder, 1992). In particular, for technology development, competition generated by market forces could induce individual enterprise towards technology protection. In such a case, government intervention is able to facilitate co-operation at the entire national level. So, although, the socialist system has shown a number of weaknesses and problems, particularly in the institutional structure for technology development of a country, the positive features of the industrial planning system should not be downplayed. As Riskin (1981) pointed out, in some accounts the negative stereotype of this system is a mirror image of that idealisation of the market to which some reformers are prone.

In respect of the argument of "incompatibility" between market and socialism, it may be plausible to believe the "impossibility theorem" postulated by Arrow (Stauber, 1987), that there is no closed and consistent socio-economic normative theory which would assert, without contradiction, a socialist value system and at the same time provide for the efficiency of the economy. History has recorded that there are no "pure" and perfectly "consistent" societies. Every real system is built upon the practical compromises of mutually contradictory principles and requirements. That is why both socialist and capitalist need to be "advanced". And it becomes necessary for socialist states to be aware of these contradictions while adopting socialist strategies and efficient means for economic development in the transition.

As already said in the beginning of this section, the above review of the recent writings of socialist theories is rather selective in relation to China's social and economic transition, and in particular the issues linking to technological development, on which the next section will focus.

2.4 Technology Studies

In this section, the first sub-section (2.4.1) deals with institutional environment and incentives for technology dynamics of a nation, wherein technological learning, adaptation, innovation are taking place. Section 2.4.2 examines two important concepts in particular: technology transfer and technological capabilities. Examination of how these terms have been reconceptualised leads on to a discussion of recent strategies for "indigenous technological capability". Section 2.4.3 is concerned with "the social shaping of technology" (SST), its possible contribution to the treatment of technology in development studies and its relevance to the concerns of this study. In particular SST's concepts of local shaping of technology, through the adaptation and even transformation of exogenous technological offerings, offers new ways of understanding the process of technology transfer and the appropriateness of foreign technologies to local environments and thus opens up possible strategies for the acquisition and promotion of indigenous technological capabilities.

2.4.1 Institutions and Incentives for Technological Development

Recent technology studies have seen extensive discussion of the contribution of social-institutional structure and government policies to technological dynamism. Scholars such as, Nelson (1992), Fransman (1991), Lundvall (1992) and Bell and Pavitt (1992), have been focusing on the national system for technological innovation in developed and developing countries. They seek to identify the essential characteristics of "best practice" of a country's national system - comprising institutions and policies and the key features which are associated with successful technological development.

Bell and Pavitt (1992) sought to distinguish the characteristics of the countries which have been successful in generating and managing technical change from those which have not. They address the features of particular firms which have different sources of and opportunities for technical change and technological accumulation; local incentive mechanisms, inter-sectoral linkages; and policies and institutions that support the development of indigenous capabilities and seek to link this to the relative performance of the country and its technological accumulation. Key features are identified as being associated with successful technological accumulation: a substantial inward flow of foreign technology, closely coupled with the rapid development of indigenous capabilities in firms; heavy investment in education, training and skills; incentives for innovation and imitation; favourable product market conditions; and institutions and policies to encourage learning.

Bell and Pavitt (1992) have systematically compared institutions and policies in developed, developing countries and centrally planned systems. They argue that the accumulation of technological capabilities must become a policy objective of a country in its own right, rather than to be treated as a by-product. They believe in the indispensable importance of the state role in encouraging technological accumulation (learning) within firms, given the risks of "market failure" in this respect.

Similarly, Lundvall (1993) criticises the presumption of many economists of the rational behaviour of economic agents and the existence of pure markets. His work also explores the relevance of national systems of innovation, highlighting the ways in which real world economic systems may be organised differently and wherein the behaviour of agents, rooted in different systems, may be governed by different rules and norms.

A series of studies have been undertaken of different countries. Many features are commonly recognised as important across different national systems. These include user-producer relationships and intra- and/or inter-sectoral collaboration.

This shift of concern from addressing the generic features of successful national innovation system towards investigating particular aspect and processes which may be associated with technological dynamism is also accompanied by a concern to examine how these may vary with different forms of technological innovation and across different technological fields. Thus Freeman and Perez (1988) and Lundvall (1993) distinguish stationary technology, incremental innovation, radical innovation and technological revolution. For example Perez (1985) suggests that the current period which is dominated by information and communication technologies and micro-electronics, heralds the onset of a new techno-economic paradigm, requiring a radically different set of social and institutional arrangements. This includes, for example a high level of industrial collaboration and government intervention. Perez further suggests that the new paradigm will offer DCs important opportunities to catch up with the West.

Apart from this work, which adopts a long-term historical perspective, most of these studies are concerned to identify particular "best practice" with a national system.

This is essentially conceived as static. This invites two criticisms. First, factors deemed to be successful in inducing innovation in one country may turn out to be less significant in a different national context. Second, national systems are not static. A national system in the real world is changing and, moreover, must change responding to the evolving world system and technology paradigms. Transition is the most dramatic case. The pace and scope of social and institutional change poses particular difficulties in achieving innovation in national systems. For example, it requires not just appropriate policies but perhaps also their rapid adjustment. With this regard, it is important to address not only the form of the institutional system and the content of policy, but also the process, timing and circumstances.

2.4.2 Technology Transfer and Indigenous Technological Capabilities

To clarify the meanings of "technology transfer" and "technological capabilities" relevant to this study, it is necessary to examine and discuss these concepts which have been defined and used by many writers.

The Earlier studies concerned with technology transfer from richer to poorer countries focused largely on the enormous problems which most developing countries suffered. These problems related mainly to the cost, suitability (or "appropriateness") and effectiveness of the technology transferred (Fransman, 1984, also section 2.2). Since the late 1970s, with the recognition of the success of certain NICs in acquiring and developing advanced technological capabilities, the assumption about the extremely weak position of less developed countries in technology transfer began to be challenged. Since then, there has been a fundamental shift in focus in the study of developing country technology (Fransman, 1984 and Colman and Nixson, 1994).

Intellectually, this shift paralleled a turn in technology studies to address the detailed processes involved in technological change in developing countries (Fransman, 1984) and in general (Mackenzie and Wajcman, 1985). Increasingly researchers became interested in what happened to technology as it was imported and assimilated by DCs. Accordingly, greater attention began to be given to the processes involved in unpacking, mastering and adapting imported technologies.

It was increasingly realised that technology was not fully transparent and involved important tacit elements, and that its transfer accordingly involved a significant degree of uncertainty. The process of unpacking, mastering and assimilating imported technologies thus required firms to solve numerous problems, the answers to which were not always provided by the supplier of the technology. The assimilation and reproduction of technology therefore itself involved a process of technological innovation, however minor (Fransman, 1984). As we see below, the process of technology transfer relates to the technological capabilities of the recipient.

Smith (1990) has distinguished four types of transactions that may be involved in technology transfer:

1) the acquisition of the right to employ a technology which is protected by a patent;
2) the acquisition of physical capital assets embodying a new technology or set of technologies;
3) the provision of technological services, whether at arm's length or through the equity involvement of a foreign company and
4) the transfer of knowledge to citizens of the host country about the technology and its use (Smith, 1990).

There have been other schema for categorising such transfer with more or less similar features and terminology. Some refer to (1) as "licence purchases", and (2) as "commodity imports", which is regarded as a mode of technology transfer when they embody technologies not available in the recipient country. (4) has been described as the "transfer through non-commercial channels" (Bornstein 1985). Bornstein (1985) breaks down (3) into two types: "turnkey plants" and "industrial co-operation agreements".

It seems to me that the choice of technology transfer modes depends on the requirements of recipient firms or nations; their strategic development plans (section 2.4.3); and their existing capabilities for mastering, assimilating and innovating imported technologies.

The effectiveness of technology transfer - including the selection of both technology and supplier, and the maximisation of the recipient's bargaining position - requires indigenous technological capabilities. For example, in the first place, strategic planning demands technological knowledge and understanding of current technological developments. A long-standing debate has been focused on the relative merits of acquiring large-scale sophisticated versus small-scale, intermediate technologies, and in the recent past increasing attention has been given to the need of acquiring advanced technologies. Experience shows that they each have a role to play in different contexts. What is essential is that developing countries need properly qualified manpower to assess competing technologies on their own merits and to select those that are found to be most suitable under the circumstance (Huq, 1991). Moreover, the recipient's knowledge about the technology concerned will be an important factor influencing its bargaining strength, e.g. the information it has about alternative sources of supply, the resources it is prepared to expend on getting such information, and, paradoxically enough, how much it knows about the knowledge it is buying (Balasubramanyan, 1973).

The longer term significance of technology transfer is the possibility of replicating knowledge and applying it more broadly, beyond the boundaries of the firm originally involved, for recipients to assimilate, adapt and improve upon the original technology transferred from abroad. Rosenberg (1985) points out that the geographic transfer of very productive forms of physical capital may be of little use, unless the appropriate human resources are simultaneously available *in situ* to provide for the operation, maintenance, repair, and upgrading of the facilities, as well as to interface with and learn from foreign engineers and specialists (Rosenberg 1985, Preface, viii).

Therefore, issues of the technological capabilities of the recipient come to the fore in relation to the technology transfer. For developing countries, effectively transferring technology requires indigenous technological capabilities. In turn, it offers the possibility of building up indigenous technological capabilities by strategically and effectively acquiring exogenous technological capabilities through technology transfer.

There have been many definitions of indigenous technological capabilities, and definitions are often closely related to the perspectives and purposes of the person using this concept. Many popular definitions identify different components of technological capabilities in relation to the process of technology transfer and put them in a hierarchical order. For example Dahlman and Cortez (1984) identified five types ordered as follows:

1) capturing technology which includes searching for available technologies, selecting ones appropriate to specific local needs and conditions, and negotiating favourable terms.
2) translating product and process knowledge into products and productive facilities.
3) operating those plants, processes and equipment.
4) improving plants, products, processes, inputs and equipment.
5) creating new technological knowledge, in order to satisfy specific needs and local conditions (Dahlman and Cortez, 1984 in A. H. Molina 1987).

Lall (1992), perhaps from an economic point of view, stresses "investment capabilities", "production capabilities" and "linkage capabilities", describes these technological capabilities as a sequence involving mastery of technology proceeding from simpler to more difficult activities. (Though he indicates that different firms and different technologies may adopt different sequences).

In my view, technological capabilities can most effectively be examined at two levels: at the basic level, it is the capability of production, operation, maintenance, resource allocation, management, marketing, etc. at the advanced level, it is the capability of innovating technologies and creating new technological knowledge. In relation to technology transfer, the former, more likely, relates to the short term objectives of technology transfer for the purpose of meeting domestic demands and can be achieved by selecting the package of technology to be transferred according to existing technological capabilities. Thus, the weaker existing technological capabilities the recipient possesses, the more extensive must be the package transferred. This may have the results that the capacity to operate, produce and maintain imported technology and any upgrading rely heavily on the technology supplier, and it therefore induces financial and technological dependencies. Developing countries transferring technology on this basis can at best hope to become a follower of their technology supplier. Compared to the basic level, capabilities at the higher level may be more crucial for the longer term development of DCs in order to catch up through technology transfer.

Regarding the accumulation of technological capabilities, there are different accounts. Many stress that technological capabilities are firm oriented. It is argued theoretically that "technology is conceived as firm-specific information concerning the characteristics and performance properties of production processes and product designs, and to the extent that it is tacit and cumulative in nature" (Rosenberg and Frischtak, 1985: p.viii in "Preface"). It is shown empirically that "most technological learning is localised in firms", and "even in the industrially advanced countries, measured R&D activities are only the tip of the iceberg" (Bell and Pavitt, 1992: pp.25). Thus, firms are regarded as of central importance in the accumulation of technological capabilities, and, at the same time, technological learning, the mechanism transforming the activity of technology transfer to the accumulation of indigenous technological capabilities. For example, Bell (1984) elaborates six different kinds of learning mechanisms contributing to accumulation of technological capabilities in enterprises:

1) *learning by operating*;
2) *learning from changing*;
3) *system performance feedback* - learning from the experience of production depends, at any level above that of the individual task, on institutionalised mechanism for generating, recording, reviewing and interpreting that experience;
4) *learning through training*;
5) *learning by hiring* - if the skills and knowledge are not available in their environment, these may be acquired through the simple mechanism of hiring the people who embody those resources;
6) *learning by searching* (Bell, 1984).

Notwithstanding technological learning at the firm level, some writers address the importance of technological capabilities at the nation level, which require not only a clear vision of strategically utilising exogenous advanced technological capabilities, but also an supportive environment for technological learning and innovation. Researchers such as Lall (1992) distinguish technological capabilities at two levels: firm and national levels. He points out that the nation's technological capabilities are not simply the sum of individual firm-level capabilities. There may be a synergy between individual firms, and more important is a common element of response of firms to the policy, market and institutional framework (Lall, 1992). Bell and Pavitt (1992) define the country's technological capabilities as being incorporated with the resources needed to generate and manage technical change, which include not only skills, knowledge and experience, but also institutional structures and linkages (in firms, between firms and outside firms) (Bell and Pavitt, 1992). The OECD (1987) refers primarily to a country's technological capabilities as the supplies of human capital, savings and the existing capital stock, as well as the technical and organisational skills required for the use. It notes the interactions between incentives and capabilities, and institutional framework: "Both incentives and capabilities operate within an institutional framework; institutions set rules of the game, as well as directly intervening in the play; they act to alter capabilities and change incentives; and they can modify behaviour by changing attitudes and expectations" (OECD, 1987, pp.18).

The above discussion leads to the clarification of my understanding of these concepts and their relationship, which is applied in this research. To sum up, there are three major points. First, as this research concerns the processes of selecting, unpacking, adapting and utilising foreign technologies and through them ultimately acquiring technological capabilities rather than the form of the commercial relationship between suppliers and recipients, the main focus is placed on the interplay between technology transfer and indigenous technological capabilities. It gives credence to the view that the process of technology transfer, of selecting, unpacking, adapting and innovating imported technologies, demands indigenous technological capabilities, while, in turn, the accumulation of indigenous technological capabilities requires strategic and effective technology transfer.

Second, closely related is technological learning, the means which transforms the exogenous technological competencies into indigenous technological capabilities. However, technological learning may be passive, inefficient and incomplete, because of the lack of incentives, resources and supportive mechanism to encourage technological learning to take place. Therefore, the national systems of innovation, which encompasses the institutional framework and incentives relating to both state interventions and market forces (sections 2.3.2 and 2.3.3) is relevant. Moreover, the national innovation system is essential to the strategic acquisition of exogenous technological capabilities through technology transfer for both the short-term demand and the long-term development of a nation; it shapes the scope for technological learning to build up indigenous technological capabilities, in particular the longer term innovative and creative technological capabilities; and it is responsible for indigenous technological capabilities at the national level - regarding materials, financial and human resources and the capacity to generate and manage technological innovations.

Finally, while exploring different strategies for effectively utilising foreign technologies, this study distinguishes the technological capability for production, operation, maintenance, resource allocation, management, marketing, etc. from innovative and creative technological capabilities, and regards them as being at two different levels, the basic level and the advanced level. It assumes that the technological capabilities at the basic level relate primarily to short term development strategies of developing countries; and the advanced-level technological capabilities in innovating imported technologies and creating new technological knowledge enable developing countries to catch up in the longer term. Also, it distinguishes a nation's technological capabilities from firm-level technological capabilities. In the main, it agrees that most technological learning is localised in firms. However, it supports that the nation's capabilities are not just the sum of the many individual firm-level technological capabilities. It argues that, in developing countries, many local firms are so weak in terms of their existing technological capabilities that assistance of other technologically related firms and institutions, such as R&D and financial institutions, become crucial.

2.4.3 The Social Shaping of Technology in Developing Countries

In respect of technology *per se*, this research is based on view of technology as socially shaped. Thus, the characteristics of technology can be changed according to the input of a broad social and economic factors.

In this perspective, technology transfer, in theory, can never be a pure process of geographic movement, rather technology will necessarily be transformed to adapt the different social and economic context. Accordingly, it may be possible for developing countries to adopt advanced technologies from abroad and make them suitable for the local environment. No doubt, to achieve this purpose, indigenous technological capabilities in the recipient country are required.

According to the theory of social shaping of technology (SST), technology does not develop according to an inner technical logic or any other single rationality, such as an economic imperative. Instead, every stage in the generation and implementation of new technologies involves a set of choices between different technical options. Alongside narrowly "technical" considerations, a range of "social" factors affect which options are selected - thus influencing the content of technologies and their social implications (MacKenzie & Wajcman 1985).

SST highlights the "choices" inherent in both the design of individual artefacts and systems, and in the direction or trajectory of innovative programmes; and it stresses the social influences and negotiability of technology. This contrasts with traditional "linear" models of innovation which divides innovation into separate phases, with a one-way flow of information, ideas and solutions from basic science, through R&D, to the diffusion of stable artefacts through the market to consumers. In this way SST criticised "technological determinist" views, that sought to exclude technological development from social analysis and explanation, and which saw technologies as requiring particular social outcomes or "impacts" (Williams & Edge 1992).

SST research investigates the ways in which social institutional, economic and cultural factors have shaped:

- the direction as well as the rate of innovation

- the form of technology: the content of technological artefacts and practices
- the outcomes of technological change for different groups in society.

It intends to "identify opportunities to influence technological change and its social consequences"; to "broaden the policy agenda"; to offer "the prospect of moving beyond defensive and reactive responses to technology, towards a more pro-active role" (Williams and Edge 1992).

In respect of technology development in developing countries, the SST perspective has some similarities with classical intermediate technology theory, insofar as it points to the way that technologies embody social and economic elements from the context in which they originated. However these two theories point to different conclusions about the scope for developing countries to transfer advanced technologies from industrialised countries and apply them to their own ends. Classical intermediate technology theories see advanced technology transfer as inextricably linked to dependency and therefore confine what they see as appropriate technology to a very limited category.

SST research emphasises the instability and negotiability of technologies. So, although values may get built into artefacts, they are not automatically reproduced when they are used; instead the possibility remains for their transformation to meet specific local circumstances. Indeed SST empirical research shows how flexibility in use is a deliberate feature of many advanced technologies such as microelectronics: technologies which were purposely designed to meet the needs of a wide range of customers, often around public or industry standards, as part of a strategy to build and exploit mass markets. The implication is that such technologies as the telephone and computer can be used not only in industrialised countries but also in developing countries. Underpinning these contrasting interpretations are very different views of technology, and their social bases.

Whereas classical intermediate/appropriate technology theories tend to see technologies as internally monolithic, and embodying particular priorities and presumptions (about social goals, about the skills and resources available in the society) which will be reproduced when those technologies are used, SST sees complex modern technologies as heterogeneous assemblages (of diverse technologies and social elements) and therefore capable in principle of being reconfigured in their implementation and use. Indeed an important feature of modern, complex technologies, such as information technologies, is their configurational nature, as combinations of standard components and customised elements, configured to meet particular exigencies of use (Fleck 1988). In the dynamics of development of information technology, many elements have become available as standardised, "black-boxed" commodities, including, for example, hardware (e.g. microprocessors, personal computers) and software (e.g. operating systems, and generic utilities such as databases, network management functions etc.) designed around their potential utility in a wide range of technical and social settings (Brady, Tierney and Williams 1990).

Although empirical SST research mainly addresses technological development in industrialised countries and some early studies can be criticised for their undue focus on the early development of new technologies, its theory provides new perspectives for developing countries to utilise and benefit from foreign technologies. On the basis of SST theories, we can see that in principle developing countries, though lacking technological resources and therefore depending somehow on foreign technologies, should still be able to apply and develop technologies locally, utilising existing foreign advanced technologies as instruments in this process. Practically, East Asian NICs have confirmed this possibility with their successful experiences.

In a broad sense, the local shaping of technology in a developing country can be seen as the adaptation and further elaboration of technology development on the basis of technologies transferred from abroad. From the viewpoint of SST theory, we can clearly see the possibilities for developing countries to acquire technological capability by transferring foreign technologies and through it to locally shape these technologies. As discussed above in section 2.2, there are many disadvantages and problems for developing countries to transfer foreign advanced technologies, e.g. the incompleteness of their knowledge of the transferred technology; the Western social and technical rationality and presumptions which may be embedded in transferred technologies which may not be appropriate for the developing countries; and trade barriers favouring industrialised countries. This research argues that the flexibility in use and potential negotiability of technologies, emphasised by SST research, invite developing countries to look into technology strategies and government policies relevant to the local appropriation and further development of technology. For example, where technology transfer only resulted in incomplete knowledge transfer, developing countries need to consider only acquiring the knowledge which is acquirable and needed at the moment. Other kinds of technological knowledge - for example needed to build "black-boxed" technological artefacts - may remain within the "black box". So to speak with regard to embedded Western rationality, developing countries have to reduce their negative effects through either selectively purchasing or locally shaping them to meet the local needs.

In these respects, of course, it becomes important to understand the scope for the flexibility and negotiability of a particular technology in its design, production and use.

From the viewpoint of developing country, the scope for local shaping of foreign technology is concerned with the characteristics of the technology transferred and the nature of transaction agreed between suppliers and recipients. It might be useful to identify some characteristics of technology employed typically in today's advanced technology transfer from industrialised countries to developing countries.

There are at least two main ideal types of technology transfer, the purchase simply of physical assets and the complete transfer of technological competencies including also foreign know-how, management skills etc. This points to a range of kinds of more or less extensive transfer. Obviously, the latter is more complex: it extends into more explicit "social" issues. In terms of the know-how, the major difference between these two is that for the latter the know-how is more comprehensive than the former and contains not only know-how of using the technology but also production, possibly re-engineering, operation, installation and maintenance, etc. Both of them include technology transfer in the form of physical assets.

Following on from this, SST also allows us to analyse the differences between different type of technologies in the form of physical artefacts. Fleck proposes a distinction between discrete technologies, component technologies, system technologies and configurational technologies. According to him, discrete technologies refer to those independent in function, not interfacing with other elements, discrete in implications and that the ultimate user or consumer can use directly. Component technologies are designed to be used in conjunction with other technological elements. They may be available as cheap standardised commodities. Public and industry inter-operability standards are critical in proving standard interfaces and reducing the cost and effort of combining components. System technologies are large scale, more complex technologies constituted around final demand. They involve complexes of elements which mutually condition and constrain one another, so that the whole complex works together. Configurational technologies, the concept introduced by Fleck, refer to situations similar to system technologies, insofar as they are complex systems oriented to final demand. However, their internal architecture is very different offering greater flexibility of development: there is no clear system level dynamic, and the system is open for further configuration (Fleck, 1988, 1988a). Configurational technologies are assembled from an array of component technologies - including both standard and customised elements - to match the application requirements.

For the purpose of this research concerning developing countries, I shall borrow some, not all, of Fleck's concepts.

Insofar as discrete technologies are stand-alone technologies designed to carry out particular functions, it may be possible to apply them widely, including in developing countries. Examples include word-processors, and computer - controlled machine tools - which relate to activities that are widely encountered (Fleck et al 1990). System technologies typically encompass a greater range of activities than discrete ones and are thus may be more tightly linked to particular applications settings. System technologies developed for use in developed countries may need to be adapted to fit them to the rather different requirements and circumstances of developing countries. However system technologies tend to be rather rigid in their construction and may be difficult or costly to adapt. An example is provided by the System 12, public digital switching system covered in this study.

Configurational technologies match the application complexity of systems technologies, but are designed to allow great flexibility in development and application. Development costs are reduced by drawing upon existing components technologies - which can be selected to match the particular applications requirements. This makes it more flexible for developing countries to reconfigure such solutions to their local needs and exigencies.

Information and communications technologies in particular are increasingly taking the form of configurational technologies. Modular design and the use of open standards facilitates the substitution of internal components. The selection of components and design for flexibility in application can make it easier to adapt them to meet the specific needs of a wide range of users. In such a case, foreign technologies can be locally configured in the developing country to meet as much as possible local criteria, such as being suitable for local production and local markets, using local resource, etc. Configurational technology extends the scope for recipient-side innovation.

To some extent every technology needs to be re-configured when being transferred from one society to another. In fact, their degree of configurability varies greatly depending on the nature of the technology design and the nature of component technologies. Obviously, the more configurable the technology, the more the technology can be locally shaped.

One important advantage of the more open architecture of configurational technology solutions is the scope for applying standardised component technologies which may be available on the market as cheap commodities (thereby offering lower prices for consumers and bigger markets and bigger profits for suppliers).

By contrast, system technologies are generally more difficult to master than configurational technologies. Their more or less unique proprietary architecture and elements mean that they embody a wide range of technological knowledge which must be acquired if a developing country is to learn how to design, make and apply the system themselves. On the other hand, the possibility of building configurational solutions from component technologies gives a firm or a nation more choices about which areas of competence they need to acquire themselves, and which areas can be "bought in" as black-boxed technological solutions. For developing countries, there are always "black-boxes" while transferring foreign advanced technology, since mastering technology or adapting technology is a gradual process. In addition, some black-boxes are more difficult or costly to open than others and the extent that they can be opened is concerned with local technological capabilities, market price and decision of suppliers. In this respect, developing countries have to concentrate on the most appropriate choice about which technology black-boxes to open and when.

So far, this section has covered discussions about importance of the broad social and economic context for technological development; and the close interplay relationship between technology transfer, indigenous technological capabilities and technological learning. These discussions point to the necessity of strategies in combining exogenous technological competencies acquirable and indigenous technological capabilities to meet local needs and exigencies in developing countries, and further lead to the adaptation of social shaping of technology approach to this research.

2.5 Summary - Rationales and Research Questions

This section summarises the key points drawn from the above long literature review and discussions of issues in three areas, and all these are related to the major concerns of this study. In the main, this establishes the theoretical framework for the study, and sets up research questions to be central focuses in the rest of the thesis.

Development or Dependency

The three intellectual traditions of development studies in post-war literature - modernisation theory, dependency theory and the intermediate technology approach - each have their strengths and weaknesses. Together they bring a wide range of perspectives for this research in relation to the scope for development in less developed countries. Modernisation theory is very much confined to the model of Western industrialisation, however, it produced a range of detailed empirical studies. These empirical studies were valuable particularly in integrating technology and the market economy, although it is largely based on the experiences of economic and technology development in the West. The dependency school of thought draws attention to the obstacles to economic and technological development in DCs. Together with associated structural approaches to understanding development, it addressed not only the economic dimension, but also other social and environmental issues and explored how the roots of underdevelopment lay far beyond the domain of less developed countries and arose from their position in the world political economy. However, its general view is so pessimistic as to provide little hope for developing countries wishing to industrialise and to acquire advanced technologies. It does not suggest effective strategies for DCs and it fails to explain the relative success of some NICs. The intermediate technology approach gives an close-up view of the problems and especially the negative social consequences of technology transfer from industrialised to developing countries, and emphasises the scope for developing indigenous technologies. However, it confines itself to a very limited choice of technologies, which particularly excludes advanced technologies.

The need for modern technological development is now widely recognised as crucial to economic development in developing countries. There are still doubts as to whether it is feasible for developing countries to catch up and overcome the existing gap between developed and less developed countries, and debates about how DCs might achieve this and thus escape economic and technological dependency. The economic success of Asian NICs has raised the hopes of developing countries. Studies of their experiences draw attention to some of the strategies which may achieve technological dynamism. However, there have been controversies about the assessment of their technological capabilities and the validity of their experiences for other countries.

This study holds a relatively optimistic view of the scope for developing countries to acquire technological capabilities while being armed with knowledge about possible pitfalls from earlier development studies. As dependency theories have clearly pointed out, no developing country can escape from the political economy of the world. Thus, for developing countries, development, including technological development, would be better seen as a race between countries, and, to a great extent, a race with the powerful developed world. It is evident that the advantages of developed countries and/or disadvantages of less developed countries are neither absolute nor fixed. For example developing countries had advantages in terms of labour costs. Advanced economies may have stronger technological competencies, which may enable them to retain markets for sophisticated high-technology products, but this situation is changing rapidly. The NICs have rapidly acquired high levels of technological competencies with a highly trained workforce. Equally economies like South Korea are now, in turn, beginning to face the problems of developed countries in the face of competition from newer industrialising countries.

China is ambitiously seeking to catch up with the developed world in both economic growth and technology. The success of Japan and the Asian NICs is a great encouragement to it, and their models of development have been of considerable interest to China. In particular, their model of strong government intervention in the process of national industrialisation and foreign trade are seen to match the Chinese socialist tradition, together with a more or less similar culture. There is considerable uncertainty inside and outside China about whether China can follow suit and achieve its ambitious targets, especially in technological development.

Through the case of telecommunications switching technology, this study seeks to explore the prospects and opportunities for technological development in China. In particular it seeks to investigate whether China is achieving its targeted objectives in public digital switching technology, which is regarded as an area of high technology. Following from the above review, a key question is whether less developed countries like China are able to build up technology competencies in high technology by importing technology from developed countries without suffering substantial dependencies.

Technology Transfer and Indigenous Technological Capabilities

From the review of research into technology in developing countries, this study concludes that technology transfer from advanced resources is necessary (section 2.4.2). Effective utilisation of foreign technological competencies can help build up indigenous technological capabilities. The selection of imported technology needs to be matched to the strategic development plan of individual recipient countries and be most appropriate for their circumstance. However, technology transfer does not automatically lead to the accumulation of indigenous technological capabilities. Rather there is the need for a broader social and economic environment encouraging the activity of technological learning.

Indigenous technological capabilities are essential for developing countries to extricate themselves from the less developed state. The technological capabilities at firm level lay the foundation for the technological capabilities at the national level, although there are differences between the two. Technological capabilities can be categorised into two groups: the basic technological capabilities including production, operation, management, resources allocation, marketing, etc.; and the technological capabilities of innovation and creation which seems to be more crucial for DCs in catching up and pursuing technological advantages in longer term.

This study highlights the close and inseparable relationship between technology transfer and indigenous technological capabilities (as discussed in section 2.4.2). The transfer of advanced technology from abroad is necessary for accumulating indigenous technological capabilities; indigenous technological capabilities are essential for the strategic and effective transfer of exogenous technological capabilities; and through learning mechanisms the activity of technology transfer - selecting, unpacking, adapting and innovating imported technologies - contributes to the accumulation of indigenous technological capabilities.

In the case of public digital switching technology in China, the aim of technology transfer involves renewing the national telecommunications infrastructure which requires a sufficient domestic production capacity for the new switching technology. More important, for the longer term, is the accumulation of indigenous technological capabilities to innovate imported technologies and create new technological knowledge for China to catch up in this area. This therefore detects at least two different purposes of utilising foreign technologies - to meet urgent domestic needs and to accumulate particular indigenous technological capabilities with longer term significance. All this requires a strategic plan for technology production and R&D development, linked to the general development strategy of the whole country.

Local Shaping of Technology

Adopting the approach of social shaping of technology, as addressed in section 2.4.3, opens up a wide range of possible strategies for the acquisition and promotion of indigenous technological capabilities. Unlike classical intermediate technology theories, the approach of social shaping of technology sees complex modern technology as increasingly configurational in nature. They are heterogeneous assemblages of diverse technologies and social elements and therefore capable of being reconfigured in their implementation and use. This is in contrast to the conventional concepts of acquiring complex technologies as finished "systems" solutions (Fleck 1988, 1988a). Applying the social shaping of technology perspective to developing countries, this research suggests that technology transfer can involve a process of *local shaping* as well as the unpacking of foreign technologies. There are, to a greater or lesser degree, choices for developing countries to alter these processes. This is not to deny the disadvantages and risks faced by developing countries in their attempts to transfer foreign advanced technologies, e.g. incompleteness of knowledge transfer; the imposition of Western values and rationality embedded in transferred technologies; and trade barriers which favour of industrialised countries. However, it suggests that these negative affects can be reduced through selective purchasing, unpacking and local shaping imported technologies according to local technological capabilities and requirements and the availability in the international market.

Through empirical cases studies, this research seeks to explore the different strategies available to developing countries, in order to examine the advantages and weaknesses of these strategies in relation to the accumulation of technological capabilities, and to analyse how such strategies may correspond with existing local technological capabilities and the local environment.

National systems of Innovation

Some studies have further shown that the process of building up indigenous technological capabilities will not be effective and complete without a supportive institutional environment and appropriate government policies (section 2.4.1). Here, the increasing interest within technology studies in national innovation systems draws attention to links between technological dynamism and institutional environment and government policies. However, there is no single or fixed model of the best system for technological innovation. Different institutional and policy contexts of a nation, different international environments, different historical traditions of the nation, each may call for different strategies for long and short term development. This study examines the Chinese innovation systems - focusing on the problems in achieving technological dynamism in China's socialist economy and the ways in which the Chinese innovation systems are changing during China's transition.

Studies of socialist economics (section 2.3 in particular 2.3.1), have analysed the marked weaknesses of socialist states rooted particularly in the central planning system and state monopoly control. From the view point of technological development, we see that the rigidity of the socialist state machine and the lack of incentives are also major obstacles to technological dynamics. As China's current transition is from a centrally planned to a market-oriented system, this study seeks to examine whether and how China's current transition has altered the elements of this national system for technological dynamics over time.

State Intervention versus Market Forces

The development studies literature relating to the success of several Asian NICs suggests that state intervention has played significant role in providing macroeconomic policies and infrastructure, formulating long-term national plans for investment and industrial development, directing the pace of industrialisation, etc. (section 2.2.2). The technology studies literature on national technological dynamism stresses the importance of information flows and collaboration between industries and other institutions relevant to technological activities, such as educational, R&D and financial institutions, and customers. It concludes that market forces and state intervention are both important and complementary in generating incentives for technological development (section 2.4.1 and 2.4.2). The literature on socialist economics comes to similar conclusions (section 2.3.3). Though many writers from the ideological right and left have sought to counterpose state intervention and the free market, this dichotomy has been increasingly called into question. Again there is a growing consensus that public intervention and market forces may be complementary in achieving sustained technological dynamism. Empirical studies show that "pure" state intervention and "pure" market mechanisms are each likely to fail.

This study is concerned with the public digital switching technologies, which are radically different from the electromechanical switching technologies they superseded. Being at the heart of modern telecommunication networks, their enormous economic and social importance give them considerable strategic and political significance. State intervention and state provision have been a common feature in telecommunications in all countries - which can be related to the enormous long term investments involved and the strategic importance of telecommunications. Even where the state is not a provider, it uses regulations to ensure the integrity and acceptable operation of the telecommunications network. The state's role in developing countries is particularly important in acquiring the necessary resources and to bargain more effectively with foreign suppliers and their governments. In this regard, China is no exception.

In the study of socialist economics and transition, the issue of diverse forms of state interventions has been raised. Policies used for the economic development in NICs include e.g. import substitution, export orientation, openness of domestic market to outside, high import tariff to protect the infant industries of the nation. Their effects whether positive or negative are still controversial. With this in mind, this research seeks to analyse the way that the Chinese government has implemented its interventions in the case of public switching technology development in the contrast of approaches being pursued elsewhere.

Another very important function of state intervention to be addressed here is the reduction of negative social consequences of economic development. This issue has been raised in development studies, as well as in the study of socialist economies. In development studies, some dependency theorists have been very pessimistic about the consequences of economic growth (section 2.2.1). The same concern has arisen in the study of socialist economies resulting in controversies about the feasibility of socialism and the incompatibility or compatibility of markets and socialism. This research recognises the contradictions between economic efficiency and other human interests, as Arrow's "impossibility theorem" (section 2.3) has pointed out. However, it is necessary for governments (perhaps especially socialist governments) to play a role in striking a balance between economic efficiency and public interests.

This research proposes that socialist governments, which in principle attach a greater priority to the majority of the people's interests, may be more concerned than others about negative social consequences produced by technology and economic development. It is equally important in pursuing rapid economic growth in developing countries, because social instability has been one of the major destructive factors. There is the need to control the pace of economic development which may impinge upon public interests, e.g. unemployment, environment problems, etc.

Research Questions

As noted in chapter 1, the two broad aims of this study are to explore:

- What are the implications drawn from this Chinese case for developing countries in general to acquire advanced technological capabilities, both through technology transfer and through indigenous technological development, and what strategies are available for this?
- What can we learn from the Chinese PDSS development process in relation to the context of the transition in China?

Within the above rationales and the constraints of the empirical case in the telecommunications switching technology in China, this review of existing literature suggests the following research questions to be addressed in this study. They aimed five main concerns:

1) Development or dependency

- How has China strategically utilised advanced foreign technological competencies in the area of public digital switching system to fulfil domestic demands for modernising its telecommunications infrastructure in short term and innovating the technology in the longer term?

- How has China dealt with the problems associated with technology transfer, e.g. dependencies or negative social consequences from which many less developed countries have suffered?

2) Technology transfer and indigenous technological capabilities

- Have China's attempts at technology transfer been effective in terms of acquiring technological capabilities? Have they succeeded in using existing capabilities and, through technological learning, further accumulating them?
- What factors were crucial in establishing the technological learning needed to transform exogenous technological competencies into indigenous ones?

3) Local shaping of technology

- What are the differences between the two strategies of technology transfer and indigenous technological development, in respect of selectively utilising foreign technologies and the scope of local shaping of these two systems? How has the combination of these two strategies served the country's requirements in the reconstruction of the telecommunications infrastructure and the acquisition of PDSS technological competencies?

4) National systems of innovation

- How has China's transition - both the opening up of market forces and the changing institutional context - impacted on the development of PDSS technology?

5) State intervention versus market forces

- What implications can be drawn from the Chinese PDSS cases about the respective roles of state intervention versus market forces?
- What are the changes of the forms of state intervention of the Chinese government over time during the transition and their links to different outcomes?

Chapter 3:

Research Design and Methodology

3.1 Introduction

This chapter explains how the research was designed and carried out. Section 3.2 presents the overall research design. It clarifies my reasons for selecting public digital switching systems as the technological object of this study and for adopting detailed case-studies as the main research method. Section 3.3 explains my preparatory work before entering the field, encompassing the identification of possible cases and preparation of the schedule of questions for interview. Section 3.4 describes the development of the fieldwork and reports how the case selection was finalised after I entered the field. Section 3.5 describes the process of data collection including obtaining access to investigation, interviewing, collecting written materials and official documents. This section focuses on the development of the case-studies through interviews with key respondents, and discusses problems encountered in the investigations, approaches and techniques adopted. In particular, it stresses that, given uncertainties arising in the course of the investigation, research design, data collection and data analysis are not clearly segregated stages in sequence, and they each have to be modified from time to time to ensure the quality and value of the research. In section 3.6, three phases in data analysis are described including: the analysis of the process of development in the individual cases; the identification of key features of the case-studies; and the selective analysis of research issues. The final section, 3.7, reflects on some of the strengths and limits of this research, as well as possible personal biases that may be embedded in it.

3.2 Research Design

As stated in chapter 2, my particular interests are related to technological development in developing countries and China in particular. My central focus is on the strategic acquisition of foreign advanced technological competencies to meet developing country's domestic needs and to build up indigenous technological capabilities. All this more or less shaped the choice of the technological focus of the study, the theoretical framework and the methodology adopted.

3.2.1 Selection of Technological Object of Study

As the study aimed to understand the strategic issues involved in the acquisition of foreign advanced technologies as mentioned above, the technological object of the case studies had to be a high technology field. My engineering background in telecommunications technology encouraged me to select public digital switching systems (PDSSs) as the specific advanced technology for this study. The main justification of this choice however comes from the nature of PDSS technology *per se*, which matches the features required in this research. As explained in section 1.2, telecommunications technology is at the centre of the rapidly developing field of electronics and computing technologies. Moreover, the public switching system is right at the heart of public telecommunications service. It has great social, economic and political significance for both industrialised and developing countries alike. Accordingly, within China, the telecommunications sector had been under the state monopoly control from the very outset, and had attracted considerable attention from the government since the economic reforms. Outside China, all large telecommunication equipment companies had lined up (especially before 1 January 1993),[1] with backing from their governments, to pursue the Chinese market.

3.2.2 Methodology

Questions still remain about the scope of the study - with important choices about research methodology, between for example large scale "quantitative" research, and more detailed "qualitative" approaches (MacKenzie, 1992). Most existing work that addresses technology development in China has focused on the "macro" level, relying on national statistics or policy statements. Such studies are not very informative about the key questions I wanted to explore, concerning how technological capabilities are acquired. Large scale surveys are also less appropriate than more detailed "processual" studies for investigating technology transfer from abroad since this is a new and changing phenomenon in China, which has only really occurred since the economic reforms of 1978 and had only taken place on a limited scale (when I started

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[1] On 31 December 1992, Chinese government announced the new policy which relaxed the strict control over the import of digital switching systems.

this study). Since the aims of this study were to explore the processes of technological innovation and their related social, economic and political context, detailed case-studies seemed to be more appropriate. It was necessary for the level of detail in the case studies to correspond to the level at which technological activities were generated and the innovation processes were carried out. At the same time, the scope of the studies must be sufficiently wide to be able to engage the main features of the broader environment in which the innovation processes were taking place and which patterned these processes.

In addition, there was the need to adopt a comparative approach for at least two reasons. First, case studies *per se* may have weaknesses. It is generally not justified to extrapolate from individual cases; consequent problems in generalising may raise uncertainties about the broader relevance of particular findings. It also provides little opportunities for unpicking the influence of the broader social context. Second, given the rationales of this study discussed in the previous chapter, the chosen cases should allow me to analyse the relationship between technology transfer and indigenous technological capabilities; to assess some of the different strategies available for developing countries to acquire foreign technological competencies in order to maximise benefit of local application; to evaluate differences of the national systems of innovation in relation to China's transition, particularly from central planning and state control to the combination of market mechanism and state interventions.

Within the limits of finance, time and access to players involved, I therefore decided to choose at least two PDSS systems - one foreign system brought into China by technology transfer, and one system developed indigenously. The aims are to compare different strategies for acquiring foreign advanced technological competencies in order to build up indigenous technological capabilities and meet domestic demands. A state-owned firm which was associated with the chosen locally developed PDSS and a joint venture which was associated with the foreign PDSS would be an ideal pair of cases. Investigating the state-owned firm would also reveal changes in the process of technological innovation taking place as a result of the economic and social transition. At the same time, the study of the joint venture, itself a new phenomenon of the social and economic transition, would provide a window on quite different behavioural patterns from the state-owned firm.

To understand not only the process of technological innovation but also its social context, I felt that the detailed case-studies should encompass a series of in-depth yet wider-ranging investigations, which would cover as far a possible all actors (individuals or institutions) involved in the technological activities, including manufacturing firms, R&D institutions and governmental organisations in charge of making or implementing policies relevant to the cases. A wide range of interviews was therefore needed ranging from workers and engineers on the shop floor to high-ranking officials in the central government. Ideally, the interviews should be with the individuals who have played key roles in the process of technological development or transfer. In chosen firms the interviews should address a range of actors including those directly involved in production or development, as well as management at from the middle to the highest levels.

This primary research was underpinned by extensive collection of information about government policies, regulations, legislation and other forms of state intervention. This is particularly important to comprehend the main features of the broader environment in which technology development is taking place. Collecting internally circulated documents and published materials and interviewing officials in government organisations in parallel allowed a better understanding of the formulation and changes over time of government policies and other type of interventions than using only one of these methods.

Given the complexity of the issues addressed in this study, I have adopted a double approach. On the one hand, I seek the detailed account of technological development processes made possible by actor-centred approaches, such as actor-network theory (Latour, 1988), sociotechnical systems (Hughes, 1983) and in particular, socio-technical constituencies (Molina 1990). On the other hand, the research design addresses the influence of broader structural and historical factors (Hughes, 1883 and others like Edquist, 1985).

The former helps to identify possible constituencies which are potentially influential to technological development. In particular, it highlights the interaction between "technical" and "social" elements - the way "the technical" is both shaped by and shapes "the social". According to Molina (1990, 1995), technological development processes involve the emergence and development of technical and social elements - machines, instruments, institutions, interest groups - that interact and shape each other in the course of the creation, production, and diffusion of specific technologies. These two groups of elements evolve and change their mix in ways which result in the technology growth or decline.

The latter seeks to understand the context within which technological processes take place, and particularly to analyse institutional structures of the national system for technological dynamism and the role government policies, and how they affect the behaviour and success of local actors. However this study is also centrally concerned to understand the character and significance of China's economic transition. The contextual part of the study therefore explores the modification and transformation of institutional structures over time in response to changing government policies and other changes in the domestic and international environment.

3.3 Preparatory Work

Having in mind the technological object - telecommunications PDSS technology - for case studies, I searched for all relevant data available in the collections of UK libraries and elsewhere. More useful information about the present development in public digital switching technology and telecommunications in general came directly from China through former colleagues of mine. This information helped me to map PDSS technologies in China and identify an initial selection of possible cases.

By then, although there were many foreign PDSS technologies being used in China, only three joint production ventures had been set up to manufacture public digital switching systems (PDSS):

- Shanghai Bell: this is a joint venture between the Posts and Telecommunications Industrial Corporation which was on behalf of MPT, the Alcatel Bell Telephone and Belgian Government, producing System-12;
- The Beijing International Switching System Corporation: this involves Siemens AG and the Ministry of Machine Building and Electronics Industry (now Ministry of Electronics Industry), manufacturing the EWSD system;
- A Sino-Japanese joint venture producing system Neax-61.

My first choice was System-12 and the Shanghai Bell joint venture as the case of foreign PDSS. This was because Shanghai Bell was the earliest established joint venture and its first contract for a technology transfer programme had been officially completed. The second choice had to be the EWSD and the Beijing International Switching System Corporation joint venture, since the Sino-Japanese joint venture project was progressing very slowly.

To improve my understanding of these chosen systems from the technological point of view, I read as much relevant written material as was available. For example, about the chosen system "System 12", I devoted myself to understand its main technical features, particularly where (and how) it differed from other major public digital switching systems used in the world. At the same time, I looked briefly into its history, e.g. how, where and by whom it was developed, and the history of transfer to developing countries.

Information about locally developed large scale PDSS technologies was very limited. I could only establish that there had been two systems, the DS-series and another system about which available information was so confusing that I could not identify even its name. I was able to find some published articles in Chinese and English about the DS-series and associated R&D through different channels, but no information about its manufacture.

I sent letters to the two chosen joint ventures in China, requesting permission to investigate. My requests were accepted by both. Some other letters were directed to various departments in MPT, seeking general support, e.g. provision of more information and permission for investigation, etc. However, I did not get a reply to any of these letters.

In the meantime, I prepared the schedule of questions for interviews, to make sure through interview I would get as much of the information I needed for this study as possible. Questions were listed under four parts in relation to different stages of innovation cycle, and each part had two separate versions, geared towards the particular circumstances of the foreign system and Chinese system respectively.

The first part of "interview schedule" addresses "initiation". In the case of the foreign PDSS system, this meant the initiation of technology transfer, e.g. search, selection of a particular technology and negotiation of the terms of the joint venture. For the Chinese system, it was the formulation of the PDSS technology R&D project. The second part was "technology development", which also has two versions: the major process of technology transfer of foreign system and the development process of the Chinese PDSS. The third was "technology improvement" and the fourth was "technology diffusion", which also sought information about the adaptation of foreign technology and further indigenous technological improvement after the technology entered the market. These questions were designed to get information at both the micro and macro levels. Some questions are straight forward, to obtain the basic information necessary for analysis. Other questions were more open-ended and inductive, encouraging interviewees to think openly and give information which they consider important or relevant and make comments in their own right. Every single specific interview needed a carefully chosen question list drawn from this overall interview schedule. For instance, when only a short interview time was given, the question list needed to be particularly concise, and the questions selected, easy to answer. The selection of questions also depended on the position of each interviewee (e.g. company manager or government official, high or low rank, etc.), the type of organisation they belong to (e.g. production company, user or R&D institute), and the division they work for (e.g. marketing or production).

When I entered the field many things still remained to be finalised. I had to decide whether to choose one joint venture from the two which had given outline agreement to be interviewed, or simply to use both. The more difficult task was to select a Chinese PDSS system, and to get access to the state-owned company which manufactures the product. Also difficult was the interviewing of high ranking officials in the Ministry of Posts and Telecommunications and other relevant departments in the central government. I needed not only to find the right person from whom I could get the information that I required, but also to get permission to interview them. The problem was that these people were typical officials (or bureaucrats) working for the organisations at the high level, which had a tradition of collective decision-making and secrecy.

3.4 Development of Fieldwork

I travelled to China in October 1992 to begin fieldwork. My first move was to get more detailed information, especially about Chinese PDSS systems. I had several formal and informal discussions with two of the country's leading switching specialists and other senior telecommunications engineers. These discussions confirmed that two locally developed large scale public digital switching systems had been technically approved by the authorities, DS-series and HJD-04, though further technical improvements were still required for a full licence to enter the entire market.

The DS-series project began almost immediately after the introduction of the first foreign public digital switching system into China in early 1980s. This was an MPT funded project and designed in the MPT's R&D institutes. The DS development project had been carefully planned, representing the attempts by the Chinese government to develop such a technology on their own, and gathering the best and available technological resources within the sector. Accordingly, the process of R&D followed more or less the existing (traditional) pattern of R&D in China. I could foresee that this would be a good case to reveal the problems of institutional structures typical of the old centrally planned system in China and incentives in relation to technology development.

By contrast, HJD-04 was an officially unplanned product, and its development process did not fit in any traditional pattern. The project had been initiated by a military research institute. The technical, financial and organisational elements required to complete the project were only built up later. Among many institutions involved in this process, there were three main players:

- The key figure who initiated this project, Professor Wu, and his Research Centre for Information Technology at a military research institute, Zhengzhou Institute of Information Engineering of the People's Liberation Army;
- A state-owned manufacturing firm under the MPT, the Luoyang Telephone Equipment Factory (LTEF) of MPT;
- A *de facto* procurement unit of MPT, the Posts and Telecommunications Industrial Corporation (PTIC).

It proved a great effort for HJD-04 PDSS technology to gain official approval. In other words, this system is a product of the new social and economic phenomenon, reflecting the country's current social and economic transformation. Moreover, from the technological point of view, HJD-04 adopts a very different technical strategy to the early developed switching systems, and one which I considered to be very interesting in relation to the acquisition of technological capabilities by developing countries.

Given the constraints of time and scale of doctoral research, I could not take up both cases and eventually chose the HJD-04, which seemed to suit this study better. Yet this case presented a great challenge, there was hardly any data available about either the system or the project because this project had not been officially approved until very recently. Certainly, there had been no publications apart from one short article about this project in a newspaper following the official approval.

In relation to foreign PDSS, Shanghai Bell was my first target of investigation. Later on, because of time constraints, I dropped the second option - EWSD associated with the Beijing International Switching System Corporation Ltd, a joint venture with German Siemens AG. Before began my interview in Shanghai Bell, I had another search (apart from the one I did in UK) of written materials about Shanghai Bell and the PDSS, System 12, as well as a couple of informal discussions with researchers and officials in the Science and Technology Committee of Shanghai municipal government, in order to get an overview of the case.

3.5 Data Collection

Although the scope of the study had been established, the research design still needed to be modified or changed in the course of data collection. A study like this, that relies on detailed case-studies as the main method of research, may well encounter unforeseeable outcomes in the course of the investigation. New areas of interest are identified as well as uncertainties and difficulties in the research. The way in which these issues are handled in the course of fieldwork is critical to the quality of the entire investigation. Because research design, data collection and data analysis are often inseparable in practice, many decisions could not be made until particular data had been collected and preliminary analysis done.

During my investigation into System-12, on the basis of new information arising from the interviews, I identified some additional people to interview outwith Shanghai Bell itself, for example:

- one of the System-12 users, Shanghai Telecommunications Administration;
- the former Chinese general manager of Shanghai Bell who took part in negotiating the technology transfer process;
- the System-12 Project Leading Group Office for Shanghai Municipal Government which jointly involved Shanghai Bell and Shanghai Municipal Government for the purpose of System-12 "technology localisation" (the actual meaning is: local production of components) (see Appendix).

In Shanghai Bell, I carried out twenty-eight interviews (see Appendix), ranging over workers, engineers, managers of most departments and both Belgian and Chinese general managers.

In the case of HJD-04, I had from the outset encountered resistance to my gaining access to the manufacturing firm, LTEF. LTEF, like other state-owned companies which were traditionally "plan-takers", had no reason to expose itself to any unofficial investigations. My approach was through the help of a personal contact in the

Municipal Science and Technology Committee of the local government which had some (but not powerful) influence over LTEF (which was more directly under the leadership of PTIC, the MPT's procurement arm) to make my investigation semi-official. Unfortunately, at the time of my first visit to LTEF, in the company of the head of the Municipal Science & Technology Committee, the director of LTEF was away and out of contact, and the deputy hesitated to risk making a wrong decision. While appearing very friendly and reassuring, he asked us to give him a day or two to get approval from his boss, but actually passed the "ball" to PTIC in Beijing where the local government has no influence at all. I had to start again, this time in Beijing. After travelling thousands of miles by train back and forth twice between Luoyang, a city at the centre of China, and Beijing, I eventually got permission.

I carried out eighteen interviews (see Appendix) in the Luoyang Telephone Equipment Factory (LTEF) of MPT in a similar range to these in Shanghai Bell and two interviews in the Posts and Telecommunications Industrial Corporation of MPT. I also spent a very informative half day with Professor Wu and his research team in Zhengzhou Institute of Information Engineering of the People's Liberation Army. The three key actors in this same technology project presented sometimes quite different accounts about its development.

To understand the broader context for PDSS and telecommunications technology development and the background of the state policy formulation and implementation, I carried out fifteen interviews with researchers and officials in a number of R&D institutes and central governmental organisations, including:

- the Economic and Technology Development Research Centre of MPT;
- the Science and Technology Information Centre of MPT;
- the State Science and Technology Commission;
- the State Planning Commission;
- the Ministry of Posts and Telecommunications;
- the Ministry of Machinery and Electronics Industries (now the Ministry of Electronics Industries) (see Appendix).

I did not have a list of people to interview beforehand. My approach was to trace the person in charge of the technology project and progress from the bottom up towards the MPT, and then to follow up lines indicated by previous interviews to find the next contacts. My access thus started with my personal connections and extended through them to the whole network of players. Once the chains of interviewees reached official bodies, it went on naturally to all who seemed to have been important in different roles and in different government departments.

A key principle in carrying out the interviews was honesty and openness. I gave great emphasis to interviewees that my aim was to disclose the course of technological development, explore any problems encountered and search for remedies where appropriate.

Most of interviews were tape-recorded. Initially, many people did not like their interview to be tape-recorded. However, after I stressed that the recording process would be controlled by themselves, they accepted and, while the interview proceeded, they did not seek to control the recording at all. While tape-recording interviews, I also took notes of the conversation. This proved very useful, not only in subsequent analysis, but also when, on two early occasion, I had two unexpected technical problems of the tape-recording. During the interview period, I tried to listen to the tapes in order to check the data collected as soon after the interview as possible. It proved very useful for me to double or triple check the reliability of the data, correct the errors and omissions and prepare for subsequent interviews.

My field work was carried out during the period of October 1992 to the end of May 1993 (I had several months off work in this period because of illness). Interviewing was interspersed with collecting written material and official documents, to utilise my time effectively and to check that interview findings corresponded with background information. I had also collected substantial written data about the general economic and social transition in China. All directly related materials had been briefly read before I returned to Britain. Thus I was more or less sure that I had in my mind a clear picture about the PDSS technology development in China and adequate materials in hand for the final writing up of my thesis, before leaving the field.

3.6 Data Analysis

The first stage in analysing the data involved transcribing. Although I had already listened to all the recorded interviews at least once, sometimes interesting lines in the interview conversation stimulated my ideas about certain research issues. These interview transcripts also provided an essential source for citation and analysis of the study. To retain their original value, I transcribed these recorded interviews by hand in their recorded language (Chinese and English).

The analysis of this empirical material involved three phases: the analysis of the process of development in the individual cases; the identification of key issues of the case-studies; and the analysis of the issues identified.

The first stage involved production of a detailed description of the process of development of both the case-studies, HJD-04 and System 12. This was an empirically focused account in which the theoretical underpinnings and research concerns remained largely implicit. These accounts analyse how a technological process was initiated and further developed; what were the external stimuli which encouraged or hindered the process; what were the problems facing the process; who played crucial roles (positive or negative) during the process; and what were the current outcomes by the time of my investigation. Each process was described in terms of the different players in the innovation cycles, which thus ensured to cover the entire processes of technological development. For the case of System 12, it was from the phase of initiating technology transfer to that of adapting the foreign technology to local conditions on marketing. Whereas for the case of HJD-04 it phased from the initiation of the indigenous development to the technological improvement after the technology entered the market. This was done to facilitate comparison between equivalent phases of the two cases. Use of this terminology does not imply acceptance of the presumption in many conventional accounts that the innovation cycle is an essentially linear process. However, analysing these phases helps to see changing behaviours of each player, technological learning taking place and the main driving forces behind individual phases.

This initial phase of analysis revealed rich material about actors and/or actor networks and driving forces behind technological development. However the level of descriptive details attained was, arguably, too great to allow systematic analysis. The next step was therefore to identify key features of interest and importance to the study and select them for further analysis.

In this second phase, specific features of the analytical focus of this study were finalised. Since the field of a study like this is so broad, it potentially touches on far too many issues which may be relevant and important in one way or another. Some of the issues that the case-studies might illuminate have already been extensively discussed in the literature (for example, general problems of management in Chinese industry); it was not a priority for me to duplicate in this research. An important intermediate stage of analysis involved selectively identifying some of most interesting outcomes of the first phase of analysis, according to the aims and structure of the study. This process was conducted with care, but was inevitably idiosyncratic - reflecting my concerns and developing understanding of the processes under study.

The final phase is the selective analysis of the research issues. The outcomes of earlier analysis from two individual cases were first compared and/or integrated. The comparison and integration have two-fold objectives: i) to compare and/or integrate between two individual cases overall; and ii) to compare and/or integrate particular elements in their structural and historical context. They were applied selectively according to different issues. For example, to understand the advantages and disadvantages of the two different strategies for utilising foreign technologies, the comparison was between the two cases, the System-12 and HJD-04. To evaluate the behavioural changes of agents in relation to the changes in the macro context in China, the comparisons and integration were between elements in different broader environment, e.g. the socialist tradition and the transition.

3.7 Reflections on the Research Process

This research, like any other, has certain strengths as well as limits.

Being a native Chinese person, I was able to communicate directly with people. In particular I was better equipped to "read between lines", compared to foreign researchers who, despite having good research skills, could end up with a sanitised "official account", or overlook important features or be misled because of their reliance on interpreters. My previous experiences of working in China - as a factory machinist, an engineer, a university teacher and a researcher on governmental projects - helped me to approach different kinds of people and get them into discussion. These experiences, ranged as they did from before the Cultural Revolution to the economic reform and onwards, also made me an inside observer of the system which had been changing. On the other hand, my period of studying and living in Britain enabled me to see China with a distance and so see things I might otherwise have taken for granted. (The current rate of change in China is so great that in a few years the emerging economic and cultural context might no longer be familiar to me.)

It is not easy to undertake social research in China, as many researchers have pointed out. One particular shortcoming is in statistics which are not always to be relied upon in China. Different organisations, e.g. a Chinese ministry, a multinational company, the World Bank, looking at the same industry or sector may well use different figures in their analysis. This is due partly to the diversity and lack of standardisation of the statistic system. For example, "the telephone penetration rate" (in Chinese 'Diàn Huà Pu Jí Lü'), can be based on two different calculations, one that counts in only main lines as a standardised method and the other counts in all available lines. The former can be higher than the latter. Which figure is chosen often depends on the occasion for which the figure is used and the interests of the organisation which is using it. The sources of the statistical data used for this study are indicated. It is fortunate that these data are used in this study for the assistance to see the situation or trends rather than forming the basis of any conclusions.

Given the pervasive atmosphere of secrecy, obtaining policy documents of any sort in China was very difficult. Many of the policies of ministries and local or central governments I quoted in this research were described and explained by officials in person and/or were cited by managers in firms that were affected by the policies, rather than being publicly documented. Sometimes, I was shown the official documents but asked not to read them in detail to conform with the rules of secrecy.

In respect of the method of case-studies used, there is an inevitable problem of personal biases. The first point I must mention here is that China is a huge country, and its diversity in almost every aspect is much greater than people outside perceive. Even people inside Chinese society can be ignorant because of many constraints, such as geographical, dialectal, cultural, etc. barriers. Not surprisingly, within China, different people can find witnesses to testify to particular interests and prejudices, which bring to their own account of China, not to mention those outside China. When individual Chinese are abroad, they sometimes serve or are often considered as authoritative judges on the past, present, and future of China. Yet, as a matter of fact, Chinese from different parts of the country may well be not able to understand each other when speaking because of different local dialects.

As I have also given my comments about Chinese tradition in this research, I am fully aware that my understanding of the society may be also constrained by my past experiences, which could also be unconsciously embedded in the entire research process from interviewing to data analysis. Since I was born and brought up in the cities on the east coast, the culture I am more familiar with is urban towns such as Shanghai, Beijing, etc. My knowledge about rural areas and other parts of China is limited to short stays during the Cultural Revolution or less than month-long visits when I was involved in governmental research projects or tourist tours.

As usual, after every research project, I have joys yet regrets. After this field work, I am happy with the outcome that almost all my interviews went well and were informative; I brought back a whole story and rich materials. However, because of the nature of PDSS technology - a complex technology with social, economic and political significance and of China's economic transition - from socialist central planning to a more market oriented mechanism, the scope of this study became very broad. Literature review seemed to be endless, and interesting issues related were numerous. This led to enormous difficulties of completing a study as such. In retrospect, given the constraints of PhD research, it is always wise to be extremely selective in setting up research themes, even though it means to suppress immense research enthusiasm and ambitions over a wide area (which can be very common to those who are interested in "technology studies" - an interdisciplinary study) which might have been genuine driving forces for PhD study.

PART II: CASE STUDIES

Chapter 4:

Historical Background

4.1 Introduction

Following the brief introduction of China's social and economic transition in chapter 1, this chapter gives a more close-up view of historical background of the Chinese telecommunications sector, the Ministry of Posts and Telecommunications (MPT), the public telecommunications infrastructure, switching technologies and industry. Specifically, it explicates the development of switching technologies in China and the conditions facing switching system producers in the past and during the transition period. In this way the chapter seeks to explain the institutional context in the telecommunications sector, in this transition period. It is also to provide a background for understanding the case studies that will be presented in chapters 5 and 6.

Section 4.2 describes general features of China's telecommunications sector and infrastructure. Section 4.3 focuses on the switching industry and technologies in the past and the transition. The final section 4.4 is a short summary.

4.2 Telecommunications in China

In the past, China's telecommunications system was one of the poorest in the world. Before the beginning of economic reforms in 1978, China's telecommunications system had been under the control of the central government and served mainly the needs of a centrally planned economy, and the Party and government organisations. At the foundation of the People's Republic of China in 1949, the country had only about 300,000 local telephone lines (East Consulting Ltd, 1995). For the next 30 years, little changed. From 1949 to 1978, the central government was the sole investor in telecommunications networks and services; the total investment of the country in fixed assets in the telecommunications sector was only 5.2 million Chinese yuan (Zheng, 1992). In 1978, China had merely 3,972,000 telephone lines compared to a population of over 900 million, with about 4 phones per 1,000 people (ITU, 1986). Telecommunications technologies in Chinese public network services lagged far behind the world level, and most telephone switching systems were manually operated.

It was the economic reform of the end of the 1970s that made apparent the serious constraints of the telecommunications infrastructure to economic expansion in China. As the country's door opened to the world, business communications within China, as well as with the world, increased rapidly. People's rising living standards also demanded telecommunications services. Telecommunications became immediately one of the most serious infrastructure bottle-necks for the economy. The low density of telephone lines and the consequent high rate of usage made the network badly congested. The call completion rate was so low that a popular saying stated that, "for delivering a message, it would be faster to cycle than make a local call; it would be faster to go in person by train than to get through on a long distance call".

The need to speed up the re-construction of the telecommunications infrastructure, by expanding the telecommunications network and modernising its technologies and services, was acknowledged. Increasing attention was given to the area. Large sums of money were allocated to the telecommunications sector from home and abroad. During the 6th (1981-1985) and 7th (1986-1990) five-year plan, with government approval, a combined total of yuan (RMB) 26 billions ($3 billions) was invested in telecommunications (East Consulting Ltd, 1995). Since then annual investment has soared. In 1993 alone it totalled yuan (RMB) 40 billions ($4.9 billions) (East Consultant Ltd, 1995). As a result, since 1985, the growth of telecommunications has outpaced GNP growth. According to MPT's figures, during the first half of the 1980s, telecommunications traffic in China grew by 17.5% a year, increasing to 24.4% annually during the second half of the decade (East Consultant Ltd, 1995). Since then these annual growth rates had jumped, rising from 40% in 1991, to 58.9% in 1993 (East Consultant Ltd, 1995).

In spite of this, the demand for telecommunications services continued to accelerate, as the economy continued to boom. In late 1992 (when my investigation in China began), it was a common sight to see people making a phone call while crossing the street in cities of the coastal area, even though the price of a mobile phone had reached 30,000 Chinese yuan (equivalent to £3,000). "Information", "economic gain" and "high-tech telecommunication equipment" begun to be tightly interrelated in people's minds. As a result, the waiting lists of subscribers for telephone services jumped from 163,000 in 1980, to 1,670,000 at the end of 1992, even though the number of telephone lines installed had increased by 15 million lines during 1979-1992.[1] Installation fees for new subscribers rocketed steeply: in 1993, the highest fee charged in Beijing was as much as 5,000 Chinese yuan (equivalent to £500) per line, and the waiting time was one year, or longer if no extra fees were paid (formally or informally).[2]

With a telephone penetration rate as low as 1.63 per 100 in 1992, China had a long way to go to reach European levels.[3] Still demand was expected to accelerate very rapidly. A Chinese scholar described this growth as involving several waves (Chen, 1993). The first originated with business users, especially organisations involved in foreign trade in the south-east coastal area. Later on, it moved inland and to the north. The most recent wave [1993] involved domestic households. There was a "bandwagon effect" associated with a complicated cultural process. When households with telecommunications equipment expanded from the emerging entrepreneur groups to include a number of "open-minded" non-business residential families, people suddenly sensed a social trend. Traditionally, Chinese culture stigmatised economic upstarts as arrogant money-worshippers, immoral-opportunists, less-educated or social-climbers. Except during the Cultural Revolution, however wealth has never been rejected by Chinese society. More importantly, Chinese people do not like to be left behind any social trends. This is especially true in the case of telecommunications. When one's friends have got telephones at home, and one is alone outside the communication network, one feels excluded from the social circle. In these circumstances, some people were willing to pay 5,000 yuan, about ten months' salary,[4] to have a telephone set at home.

Economic and social demands had placed great pressure on the Chinese government. Tight budgets could not meet the needs of modernising the whole country's

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[1] These figures are according to the internal circulated materials issued by MPT.

[2] This figure is according to my interview with Chief Consultant of the Economic and Technological Development Research Centre of MPT and confirmed by several other officials in MPT.

[3] There were 60.95 telephone sets per 100 inhabitants in total OECD countries in 1985. (Ypsilanti, 1988)

[4] This can only be a rough estimate, since it is difficult to know people's real income nowadays.

telecommunications infrastructure. Financial pressures led the central government to adopt a set of decentralisation policies intended to raise the necessary funds. First, local Posts and Telecommunications Administrations,[5] were made responsible for the local infrastructure and allowed to raise funds from various local sources - for instance, from local government, business organisations, and individuals. Second, government control over telecommunications charges (which had remained unchanged for several decades) was liberalised, with the result that Ministry of Posts and Telecommunications (MPT) adjusted charges in 1980s, and local Posts and Telecommunications Administrations were given scope to make certain additional charges to meet their own circumstances. Given these policies, many local Posts and Telecommunications Administrations set out to muster funds, including foreign soft loans. Many of these soft loans involved a stipulation (by the foreign government) to purchase foreign switching systems; this took purchasing decisions out of the control of MPT.

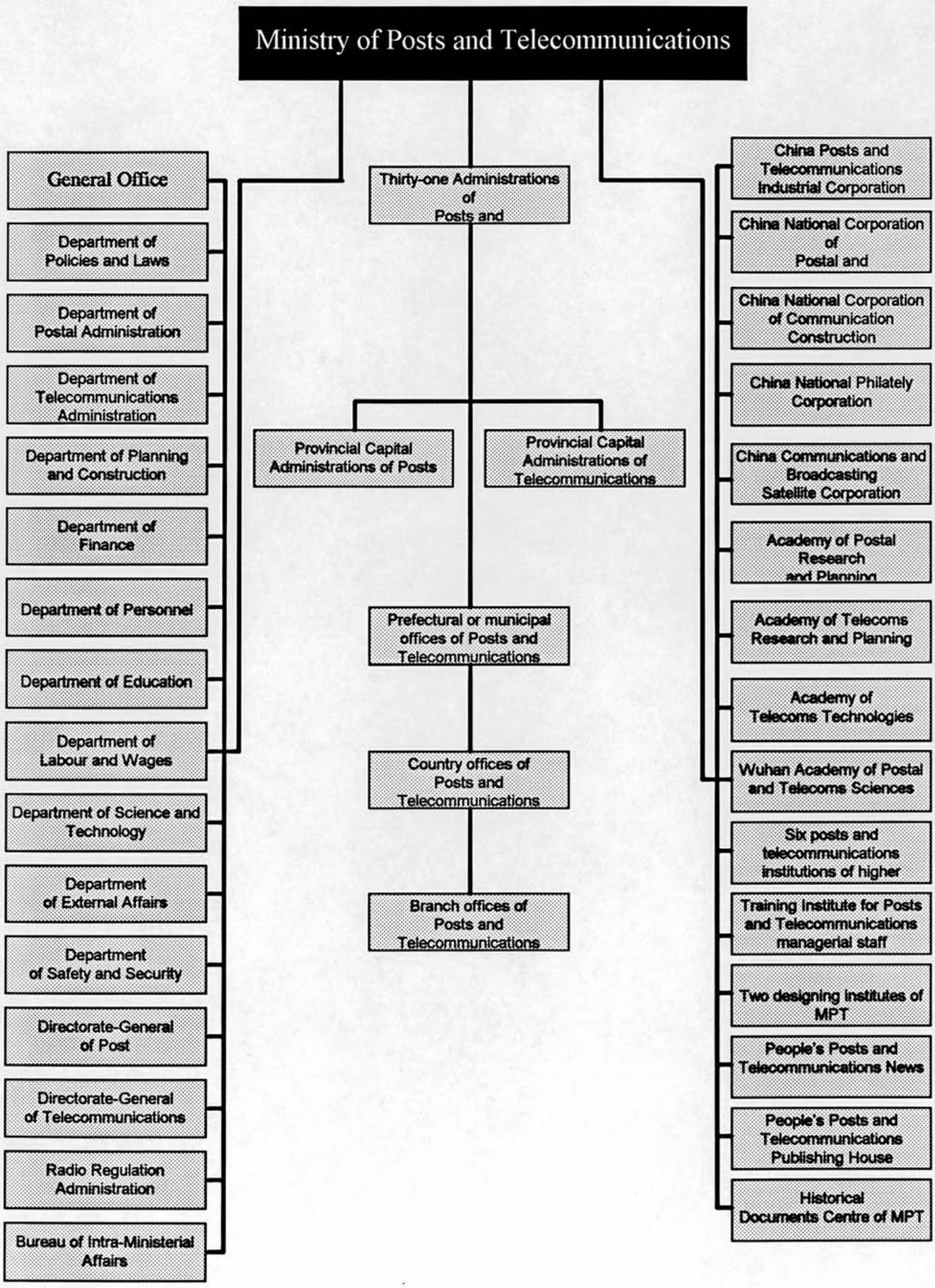
Central government issued new guiding principles to solve the fundamental problem of the lack of modern telecommunications technologies. This involved three steps: first, buying advanced technology products from overseas; second, transferring technologies by setting up joint production ventures; and third, developing Chinese technologies. This was in line with China's general strategy of dual technological development, which extended to PDSS technology.

4.3 Switching Industry and Technology in Transition

The Chinese telecommunications sector was one of the most monopolistic industries. Since the founding of the Ministry of Posts and Telecommunications (see Figure 1.) in November 1949, it was a centrally controlled independent sector. It had its own financial, material and human resource systems. No local governments and no other

[5] Each province, autonomous region, and municipality has its own Posts and Telecommunications Administrations to administer the MPT's policies locally.

Figure 1.



Source: MPT (The Economist Intelligence Unit, 9.1995) organisations were allowed to take part in managing its business. It was regarded as quasi-militarised. Furthermore, during the cultural revolution, in 1969, the "telecommunications" sector was separated from the "posts" sector and its control resided in the People's Liberation Army. From 1973 when the MPT was re-established till to the 1979 economic reform, the MPT retained a very strong monopoly position in the country. During this period, it reinforced its own productive capacity, establishing 28 manufacturing firms in total. Economic reform has led many ministries gradually to decentralise control over their companies. However, the MPT, instead, reshuffled its organisations and rearranged these 28 manufacturing firms under the leadership of the Posts and Telecommunications Industrial Corporation (PTIC) which was founded in 1980 (Gu Ming, ed. 1992: pp. 16-21). Although MPT appeared to loosen its control over these firms, it still retained considerable influence through the PTIC. For these firms, this was only a change from one headquarters to another.

Therefore, for a quite while even after the onset of economic reforms, all switch producers under the MPT retained their traditional status: they were still state-owned; their material suppliers, annual production volume and technology development projects were all decided by MPT; and end products were provided to users through the same system. In the early 1980s, they were still producing cross-bar switches.

On the other hand, soon after the inauguration of economic reforms, China begun to explore opportunities to transfer more advanced switching technologies from abroad and seek partners to set up joint production ventures. However, instead of setting up manufacturing bases, most foreign companies preferred to sell their finished products directly into the Chinese market. From 1980 onwards, when the first PDSS, F-150, a Japanese system, was installed in the southern province of Fujian about ten different systems from eight countries had gradually entered the Chines market, including System-12, EWSD, Neax-61, F-150, E-10b, System-X, AXE10, and etc. China's PDSS market came to be dominated by foreign systems.

Some multinational telecommunications equipment companies recognised the importance of Chinese markets in the long term. They responded quickly to China's call for technology transfer and were also willing to bring in capital to set up join production ventures. By 1991, three joint production ventures had been set up (section 3.3).

After these three joint production ventures were set up, a request was issued to restrict the variety of foreign systems operating in the public network. It was based on the argument raised sometimes ago that the variety of different types of foreign PDSSs had already brought about the complex interfaces in network, difficulties in maintenance, spare-parts supply, and mastery of software techniques (State Science and Technology Commission, 1986). However, the debate on whether or not it was necessary to tighten controls over the range of foreign system types ended in controversy over costs and political risks. Some studies were conducted in order to find a better solution, but *de facto* the opening up the market weakened MPT's monopoly control. The Chinese government came under enormous pressure from the demands of the domestic market and state financial shortages, as well as from foreign governments. Finally, under increasing pressure from the government of the United States of America, the Chinese government had to make a concession - not only to keep the market open but also to open it still wider. Since 1 January 1993, in response to conditions imposed for China to rejoin the General Agreement on Tariffs and Trade, the tariff for direct imports of PDSSs has been reduced, and the other two PDSS technology transfer projects, from AT&T and Northern Telecom, have been approved by the government.[6]

Following the government policy of decentralisation, customers (i.e. the local Posts and Telecommunications Administrations) preferred foreign advanced systems, even at much higher prices, to low-price Chinese cross-bar technology. Indeed, the 1980s was a decade of "foreign technology fever" in telecommunications. Orders for cross-bar products decreased sharply, and many cross-bar switch producers were running at a loss. There were two alternatives for the Chinese switch industry to go: either develop new technology indigenously, or bring in foreign technology and capital by setting up joint ventures.

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[6] According to my interviews with several officials in the MPT and the MMEI, 4.1993 in Beijing.

In the event, foreign technology was so much in demand that government policy gave privileges to joint ventures: these included low tariffs, autonomy in personnel recruitment, and less control over management than in a state-owned company. In some instances, locally produced foreign systems were treated as Chinese systems, e.g. MPT provided subsidies for local Posts and Telecommunications Administrations to buy locally produced System 12, when Shanghai Bell was running at a loss.

While joint ventures were booming, local state-owned companies were suffering. The transition from a centrally planned system to a market system had been uneven across enterprises. Joint ventures and new private companies were not subject to the traditional constraints on state-owned companies, whereas state-owned firms had inherited heavy social and economic burdens which were difficult to change.

In the socialist tradition, state-owned firms made up the industrial foundation of socialist China. They functioned not only as a manufacturing body but also as a staff community undertaking extensive social services for its members. State-owned firms had unduly large work forces and people's job were permanent. Once one entered the factory, one became a member of the community; even one's dependants were included in the welfare schemes. Under this system, the resources of materials and manpower (including all staff from managers to labourers) were allocated by the state; financing was controlled by the state; the volume of production was decided by the state, and even its products were assigned under ration to users, all in accordance with the state's plans. Incentives were provided by the inspiration and commitment of the people, encouraged by mass education in socialist and communist thought. Workers were supposed to be masters of the firm and, in turn, the firm took care of their well-being.

By the mid-1980s, there had already been a profound change: state protection gradually decreased as state-owned companies were pushed into the market place. Existing institutional arrangements - once well suited for the central planning system - did not fit the new circumstances. In particular, having a substantial work force, previously regarded as an advantage, became a heavy burden, and incentives which worked in the past were no longer effective. This rigid system of jobs for life and wages dissociated from individual's performances was popularly known as "eating from a big rice bowl". The most notable feature of the state-owned company was its low productivity and its inefficiency. In the transition a much higher percentage of state-owned companies than other enterprises in the country were running at a loss (Sun, 1992). State-owned companies all over the country had been facing increasing challenges in the changing economic and social environment.

This was also true of state-owned companies producing telephone switching systems. Unlike the joint ventures, they were struggling to become profitable, and many were on the edge of bankruptcy. They faced two challenges: first, they needed to develop workable new technologies to replace the dated technology of cross-bar exchanges; second, they needed to restructure their operation. Moreover, state-owned firms were competing with joint ventures from an unequal position. This was due largely to the uneven pace of reform with respect to different parts of the state machine - that is to say, government policy, the legal system, tariffs, and so on.

The introduction of foreign switching technologies created new problems. Foreign systems, although advanced and sophisticated, were not suitable for the poor conditions of the Chinese network (see section 5.3 and 6.4). All these systems, to varying degrees, encountered severe problems. Lacking PDSS technology of their own, the Chinese were dependent on foreign suppliers who controlled not only technologies but also the market prices.

As a part of the government guidelines for three-step technological development strategy noted early, in 1983 China established an R&D project to develop its own PDSS technology under a state scheme.[7] The earliest switching system, DS-2000, was based on the knowledge of Japanese system F-150. The project was successfully completed in 1986. Subsequently, a more advanced version, DS-30, was developed.[8] During the same period, another system was being developed as a joint project

[7] This is a state supported scheme for technological innovation, which selects various technological projects considered to be of national importance. In China, the state has been running "Five-year Plans" since 1953, which, in respect of Science and Technology development, have included a series of national R&D programmes. The R&D project for PDSS technology was under "the key project plan during the sixth five-years".

[8] This is according to my interview with Prof. Liu Ximin, specialist on telephone exchange technology, the leader of R&D project of Chinese system DS-2000 development, 3.1993 in Shanghai.

involving a military R&D institute - the Centre for Information Technology (CIT) in Zhengzhou Institute of Information Engineering of the People's Liberation Army, and a state-owned manufacturing company and the industrial unit of the MPT. It is this development of HJD-04 that forms the central focus in my second case, as a contrast to the Shanghai Bell joint venture case study of System 12.

4.4 Summary

In the past, China's telecommunications system was one of the poorest in the world. The socialist centrally planned economy had contributed little to the construction of a telecommunications infrastructure.

It was the economic reform which made the whole nation realise that this placed serious constraints on the country's economic expansion. The central government, as well as local governments, therefore, gave priority in investment to the telecommunications sector, to expand the telecommunications network and modernise technologies and services. Apart from this, Chinese culture helped build up the "bandwagon effect" and speeded up the demand for telecommunications services. All these together provided an extra capital resource for the investment in the telecommunication network. More important was that the Chinese government decentralised partially the tight control over the telecommunications sector and introduced to some extent market mechanisms. This brought in various resources from local governments for investment, at the same time allowed different telecommunications products from overseas to compete in the market.

The strategy of the state for the longer term technological development in China, involving the transfer of advanced foreign technologies alongside indigenous technological development to build up technological capabilities was applied.

Thorny problems facing the Chinese switch producers were the long standing monopoly tradition in the telecommunications industry, as well as the uneven development of new economic system combining state control and market mechanisms. Those who suffered the most were state-owned firms. In the course of introducing foreign advanced technologies into the Chinese telecommunications market, the domestic industry was put under intensified pressure of the lack of financial support and lack of new technologies. While new types of enterprises, such as joint venture and private companies, emerged and were supported by the state during China's transition period, state-owned firms were struggling with inefficiency stemming from the previous socialist tradition. The same phenomenon, on the other hand, became a driving force to compel the domestic industry to strengthen itself through technological learning and the development of indigenous technologies.

The two case studies investigated here were chosen to illuminate both technological strategies as they unfolded in the context described here: the systematic transfer of advanced foreign PDSS technology, System 12, through a joint venture; and the indigenous development of PDSS technology, HJD-04. These two cases will be examined respectively in following two chapters.

Chapter 5:

The Case of A Foreign Public Switching System

5.1 Introduction

The System 12 technology transfer project could be considered to be an archetypal example of how a country could achieve a quantum jump in technological capabilities by importing an entire advanced technology, including production capacity from abroad. The technology transfer project was initiated, and carefully planned by the state. It was one of the largest advanced technology transactions in the history of China's foreign trade. I investigated this project in China from November 1992 to March 1993. This chapter provides a detailed account of the findings of this case study. This focuses on the process of acquiring advanced foreign PDSS technology in the System 12 technology transfer, through the establishment of a joint venture project - Shanghai Bell. It highlights the problems encountered in developing System 12 production capacity, and the subsequent 'domestication' of capabilities to manufacture the components required, and how these were shaped by the changing context of China's economic reforms.

This chapter is divided into six sections. Section 5.2 explores how this technology transfer project was initiated: it highlights the role the Chinese government played in the first place, in line with its policies for technology development in the country; and how the international environment was responding to the potential Chinese market and the Chinese intention of acquiring advanced technologies. It also describes the scope of the System 12 technology transfer. This provides the framework for understanding the implementation of the technology transfer, and sets the parameters for the future development of System 12 technology in China. Section 5.3 is about the early efforts of Chinese to adopt System 12 technology - in its broadest sense, including not only technologies of the switching system, production technologies, engineering and services, but also management. Section 5.4 focuses on the process of assimilating the foreign technologies. Section 5.5 examines the formally organised technological learning activities. The final section 5.6 presents a summary and conclusions of this chapter. Drawing on this, it also raises some issues for further analysis in the final part of the thesis.

5.2 The Initiation of System 12 Technology Transfer

The System 12 technology transfer was set up immediately after the inauguration of economic reforms in China. This demonstrated the Chinese government's early determination to build up indigenous technological capabilities by acquiring advanced foreign technologies. The central government played an important role in searching for collaboration and setting up this project. The section gives the details of the Chinese government's objectives through this technology transfer; the international environment for such an advanced telecommunications technology transfer; how the central government conducted this initiation process; and the scope of this technology transfer.

5.2.1 First Move - Searching, Mutual Selecting, Negotiating

As mentioned in chapter 4 the Chinese government decided from the outset that direct import of finished foreign systems could only be a short term solution for China. As the most populous country in the world with a huge potential market, transferring technologies by setting up joint ventures was considered necessary for China to increase local added value, maintain local employment and speed up the process of industrialisation; and more important, through technological learning, to build up indigenous technological capabilities. Facing pressing demands for an adequate telecommunications infrastructure, MPT approached almost all the prestigious telecommunications companies all over the world, to explore opportunities for technology transfer through joint venture projects. At that time, several state councillors and premiers, during state visits to industrialised countries, explored the possibility of transferring foreign switching technologies.[1]

However, at that time, most telecommunications companies in the world were only interested in exporting their finished products into China. Bell Telephone Manufacturing Company (BTM) was one of the few who attempted to exploit the potentially huge market through wholesale technology transfer of manufacturing, components through a completed turnkey project.

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[1] Interview with China's leading switching experts, Xie Xiaoan and Liu Ximin who themselves involved in such overall search of the opportunity of technology transfer from outside China.

"In 1980, BTM was convinced that its technology could be successfully transferred to the People's Republic of China", given China's "skilled personnel, sound Chinese financial policies, and a suitable partner, PTIC" (Zhou[2] and Kerkhofs[3], 1987: p.186). Obviously, the attractions of a potentially large market and the opportunity for long-term technological and commercial partnership with a successful local manufacturer were key elements for BTM in their decision to draw up a contract for the technology transfer project. The first preliminary agreement between BTM and PTIC was therefore signed in Luoyang,[4] in November 1980. PTIC initially proposed that this joint production venture would be situated at the LTEF factory. BTM preferred an alternative location. The final agreement was to set the joint venture at the factory of another MPT telephone exchange producer in Shanghai.

The Chinese side was convinced that System-12 was, at that time, the most advanced technology as well as the technology the most appropriate for the Chinese telecommunications network. For example, System-12 was the only switching equipment available at that time with fully distributed-control. It was designed to avoid the weakness of central control systems, so to be relatively fail safe. It was able to handle the complex user-interface and large call processing which was essential to operate in China. ITT's (International Telephone and Telegram Corporation) reputation was an additional attraction, as, at that time, BTM was a daughter company of ITT. In addition to these functions, the Belgian government had agreed to issue a long term loan at a "country to country" level, which guaranteed the Chinese continued financial support. The most important was that BTM agreed to transfer technologies for component production, including the production technology of its custom LSI (large scale integration) chip. This was remarkable. At that time no other supplier was prepared or able to offer the transfer of such advanced technology.[5]

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[2] Zhou was the director of the Shanghai Telecommunication Construction Bureau in overall charge of the System-12 project, and the Chairman of the board of the Sino-Belgian joint venture, Shanghai Bell, at that time .

[3] Kerkhofs was the programme manager for the BTM-China contracts in 1985, and the general manager of Shanghai Bell in 1986.

[4] The city where LTEF is located.

[5] Interview with Xie Xiaoan (see footnote 1), and other interviews in Shanghai Bell.

The initiation of the System-12 technology transfer project involved the Belgian and Chinese governments, MPT, BTM, ITT and PTIC. Since this was by far the largest high technology transaction in the history of China's foreign trade (Zhou and Kerkhofs, 1987), the Chinese side set up a strong negotiating team. Within this team, the Chief Representative was a deputy minister of MPT (also a senior specialist of telecommunications technology). Many senior experts in both technologies and foreign trade from various state institutions also took part. The negotiation was an arduous marathon lasting 33 months. As far as the Chinese side was concerned, the major technological issue was whether the System-12 technology suited the conditions of the Chinese telecommunications network. For this, the features of System 12 were checked one after the other. Trade negotiation was also time consuming. The whole process was a challenge for the Chinese team. As noted above, the most thorny issue was the transfer of the production technology for the custom LSI chip, as it was a high technology within the category of COCOM's (Co-ordinating Committee for Multilateral Export Control) restrictions.[6] The Chinese side insisted that all the technologies of component production had to be included in the transaction, lest component provision be stopped in future as result of a change in political relations between two countries. On this issue alone, both sides took a year to reach an agreement.

BTM undertook to lobby COCOM to ease the control.[7] The Belgian government, from time to time, took up the matter as its involvement became necessary. In 1983, the Belgian Minister of Foreign Affairs sought to convince the US government to lift the restrictions against China. In June 1985, even the Belgian Prime-Minister intervened. The Belgian Embassy in Washington acted on behalf of the Belgian government in obtaining the US government approval for LSI technology transfer. In this period, BTM delegations had travelled frequently to Washington and Paris to pursue this goal. Even ITT was involved in these efforts. In March 1987, the transfer

[6] In 1949 the USA, Japan, and the NATO countries created COCOM to restrict the flow of strategic goods and know-how, concerned that technology transfer might strengthen the strategic and military potential of socialist countries. Industrial sectors such as electronics and telecommunications were of particular concern in this context.

[7] Information provided by the first Chinese general manager and the present general manager of Shanghai Bell on my interviews in February 1993.

of the chip (LSI) production technology to Shanghai Bell, at last, obtained an approval from the USA and the other relevant governments.

5.2.2 Scope of the Technology Transfer

The contract for the rest of the technology was agreed and signed on 30 July 1983, before the final agreement on technology transfer of the LSI chip. BTM's equity share amounted to 32% of the total, the Belgian government contributed 8% and the PTIC of MPT shared the remaining 60%.

According to the contract, PTIC was primarily responsible for providing land, buildings and necessary facilities for the plant and for exploiting the domestic market for locally produced System 12 exchanges; BTM provided the technology together with various services; and the Belgian government contributed capital. The joint production venture, Shanghai Bell Telephone Equipment Manufacturing Company (Shanghai Bell), was registered with capital of $27,000,000 US dollars and designed to produce 300,000 lines per year of System-12 switches (Shanghai Bell, 1992).

The technology to be transferred between BTM and Shanghai Bell included manufacturing and installation technology, as well as engineering technology. This was to be carried out during the contractual period of 15 years with an extension-option for a period of 5 years. It concerned the transfer of hardware and software technologies. The hardware technologies included: custom LSI production of 3 micron CMOS and 8 micron Bi-MOS; thick film hybrids, double sided and multi-layer printed circuit boards, and assembly line technology; computerised test facilities; and numerically controlled equipment for piece part manufacturing. The software included full Country Development Engineering (CDE) and Customer Application Engineering (CAE) capabilities and computer systems.

BTM was committed to transfer all the technologies that the Chinese requested. However, the Chinese did not order all the technologies, but only those which were considered necessary. For example, the Chinese did not use the fully automated production assembly that BTM used in its own factories, in order to save on capital costs. The Chinese decided to conduct manually many jobs which could be carried out by hand without having an impact on production quality.[8] In other words, where possible, the Chinese preferred to use labour rather than expensive automatic machines. Some equipment which they judged they could make in China was also not ordered. One example is the automatic operator-position, which was later developed jointly by Shanghai Bell and a local university.[9]

The earliest System 12 technology transferred was the release 5.0 based on the evolution line circuit technology,[10] which at that time was the latest version. Subsequently, Shanghai Bell selectively transferred the later innovations of System 12. In 1989, Shanghai Bell obtained the last development of the version 5 - release 5.2. In 1992, a new contract between BTM and Shanghai Bell was signed, deciding that the project of technology transfer would extend for another twenty years from 1994 to 2014.[11] The new version of System 12 to be transferred was release 7. With the hardware, the size of the exchange would be smaller than the existing one - release 5. With the requisite software, release 7 was able to provide ISDN (integrated services digital network), IN (intelligent network) and so on, as well as to meet the new requirements of the international standards body CCITT. The new contract also included an updated technology for manufacturing LSI with 1.2μ. The registered capital of the company increased to $40,000,000 US dollars and the planned annual production volume from 1995 would be 4,000,000 lines (Shanghai Bell, 1992).

5.3 Adopting the Foreign Technology

From the outset, the Chinese decided to adopt the foreign technological capacity as a whole, not only technologies for production, engineering and services, but also institutional organisation and management. The Chinese side believed that, only after adopting all these, would it be able to judge whether they are appropriate for the Chinese environment. To this end, considerable effort was made by the Chinese. The

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[8] Interview with the Deputy Manager of Operation Department, 6.11.92.
[9] Interview with the Deputy Director of Engineering Department, 30.1.1993.
[10] The development of switching system technology is characterised according to the circuit technology. The earliest is 'analogue line circuit' with a micro-processor controlling 60 lines; the next one was 'Evolution line circuit' with a micro-processor controlling 128 lines and the newest one is 'New generation line circuit' with a micro-processor controlling the same lines as the former one but the number of modems reduced.
[11] Interview with a deputy director of Engineering Department, 30.1.1993.

Belgian company's experience in technology transfer was also crucial. In spite of this, Shanghai Bell encountered a range of acute problems. These resulted variously from the technical imperfections of System 12 *per se;* and the inappropriateness of this technology to the Chinese environment; common problems of using foreign equipment and services, e.g. maintenance and spare parts supply; as well as the weakness of indigenous technological capabilities, particularly in relation to production quality.

Chinese government policy and its direct support for Shanghai Bell helped the company out of the crisis which arose at the beginning of production, and provided the joint venture with privileges - e.g. low tax, autonomy in management, human and material resource supply etc.- which allowed Shanghai Bell to conduct its business free from many of the constraints from which local firms were still suffering.

Section 5.3.1 first describes the implementation of technology transfer. It then (5.3.2) illustrates the difficulties that Shanghai Bell encountered, especially concerning the weakness of Chinese indigenous technological capability in production and quality control; and incompatibility between System 12 as a foreign developed technology and the environment of Chinese industries and the poor condition of Chinese telecommunications networks. It also depicts the prestige that Shanghai Bell had enjoyed during the early stage of economic reform because of direct government support as well as the general policies favourable to joint ventures like Shanghai Bell.

5.3.1 Implementation of the Technology Transfer

The product and manufacturing technology transfer had three phases. The first comprised the assembly of components or parts as well as testing, including incoming inspection, the assembly and test of cables, back-panels, printed boards and racks. The entire process undertaken was to BTM standards: it used the most modern production and test facilities; all components or parts and other materials were directly imported from BTM or from the companies which BTM specified; every single incoming item and each sub-assembly was inspected. This detected quality control continued until the final system tests which were followed by a performance trail (Zhou and Kerkhofs, 1987).

The second phase involved the building up of a workshop for the production of printed circuit boards and metal and plastic piece-parts. Again, these were all a copy of the BTM's, from workshop equipment, functional tests over all sub-assemblies, to waste water treatment and etc. The installation of the equipment was completed by the end of 1986, and the production line was brought into operation in the first quarter of 1987 (Zhou and Kerkhofs, 1987)

The final phase was the manufacture of the LSI chips. In order to save capital investment, instead of following the original plan to establish a completely new production facility in Shanghai Bell, a new arrangement was agreed between the Chinese and Belgian sides to set up a joint venture, between Shanghai Bell and an existing chip producer - the No. 14 Shanghai Radio Factory, to manufacture the chip. Under the new arrangement, the No. 14 Shanghai Radio Factory contributed 60% of the equity and Shanghai Bell shared 40%. This new contract was signed in September 1988, and the joint venture was named as Shanghai Belling. Product and manufacturing know-how were transferred from BTM via Shanghai Bell to Shanghai Belling for System-12 custom LSI chips. In the middle of 1991, Shanghai Belling began to provide System-12 custom LSI chips for Shanghai Bell (Shanghai Bell, 1992).

As well as hardware, transfer of engineering know-how was essential to foster a batch of Chinese engineers able to perform independently. There were two major areas - CAE (Customer Application Engineering) and CDE (Country Development Engineering), which were needed to allow the Chinese to adapt the system and build operational software packages to meet specific custom applications. CAE is the know-how by which the system is made according to individual customer requirements, as each exchange office has its specific physical layout, and each exchange requires a different number of subscribers and trunk lines with different conditions. The hardware know-how involved mastering the techniques of enabling specifications to be prepared for manufacturing; software expertise was required to understand and operate programmes, in order to produce the system load tapes for each exchange.

The CDE was necessary for the system to be customised to meet the specifications of the Chinese network. For example, in China the telecommunications network embraced exchanges of different generations, which were using different signalling systems, the System-12 therefore needed specially designed software to identify these signals. Furthermore, as the specifications for the network had been updated over time by MPT, CDE know-how could enable the system to follow the changes.

Hardware and software installation and testing in the field of each exchange office were critical undertakings. The first locally produced System-12 was installed in 1985 and however was not cut over (brought into operation in place of the existing exchange) until a year later in December 1986. This was the most problematic and critical time in the early stage for Shanghai Bell (section 5.4).

The technology was transferred by means of technical assistance, management participation, training and documentation. During the "pre-operation" period and the early years of operation, technical assistance by BTM reached the highest level. Later on, the number of Belgian engineers gradually dropped. Since 1987, after the inauguration of the first exchange, the Chinese had taken over all positions, and were able to operate the whole process by their own. In December 1992 (the time of my visit), there were merely three Belgian technical assistants left in Shanghai Bell, compared to over 12, on average, during the first three years of operation.

Management participation began with an attempt of copying BTM's style, encouraged by the Chinese government's desire to introduce modern management methods into national enterprises. The posts of Director of Shanghai Bell, and of Managers of engineering and quality control departments were held by BTM experts. In the first six years, all Belgian managers sent to Shanghai Bell had strong engineering background. With the increasing technological capability of the Chinese engineers' and rapid expansion of production, managerial problems came to the fore. In 1991 BTM, for the first time, appointed a managerial expert to be the Belgian general manager of Shanghai Bell in order to enhance management (section 5.4.5).

Since 1989, Shanghai Bell's production capacity had been increasing rapidly. Compared to its designed annual capacity of 300,000 lines, its actual output was

336,000 lines in 1989, 455,000 lines in 1990, 736,000 lines in 1991 and 1,380,000 lines in 1992. "Chinese has produced four times than what was foreseen in the beginning. This is a great growth, unpredictable!", as the Belgian general manager of Shanghai Bell concluded.[12] Furthermore, the production volume continued to increase to 2,700,000 lines in 1993 (Shanghai Bell, 1992). The expansion rate was not 10% as at most other companies, but at about 100% per year. According to the plan, at the end of 1994, after the completion of new workshops, the annual production volume would be 4,000,000 lines.[13] Shanghai Bell expected to be the one of the largest exchange producers in the world by that time.

5.3.2 Difficulties and Privileges

Quality control in the process of production was the main issue in Shanghai Bell, while production capacity was rapidly expanding. In 1989 the first year of full-scale production, the Department of Productivity and Quality Management was set up in Shanghai Bell, with a Belgian quality control specialist in charge. [14] He set up routines in the production process in line with world class standards including motivation, examination in each section, regular reporting, record-analysis and internal and external auditing. As with BTM, the target of production quality control in Shanghai Bell was to reach the level of ISO (International Standard Organisation) 9001.[15] A year later, a young Chinese engineer took over the position. However, the level of quality control was not attainable in the short term, since it is closely related to people's understanding which are associated with their living environment and general culture. Because of the old tradition, for many, the "quality" of production was merely a question of reject rate. A Belgian manager had a vivid explanation:

> You should not expect there will be a overnight change. Quality is, first of all, the people's perception. Look! (standing by his office's window, he pointed through the window, to the area - one of the poorest housing areas in Shanghai, where Shanghai Bell's workshops are located) People are living in

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[12] Interview with Mr. De Graeve, who was the fourth Belgian general manager. His predecessors were: Mr. J. Loontiens, Mr. M. Kerkhofs and Mr. S. Abbeloos.

[13] Figures was provided by a deputy manager of engineering department, 30.1.1993.

[14] According to the director of the Productivity & Quality Management, "He is a very experienced manager. Apart from building up a quality control system in Shanghai Bell, he also introduced his knowledge to other local companies and had a very good relationship with Shanghai Quality Management Association". (Director of Productivity & Quality Management, 9.11.1992)

[15] Most detailed material about production quality control was provided by the manager of Department of Productivity and Quality Management on the interview, 9.11.92.

> the environment like these. How could you expect them to have a good sense of quality?! (Director of Engineering Department, 2.2.1993)

The young director of the Department of Productivity and Quality Management described the current situation:

> Workers are still not aware enough about the importance of quality. There are two major problems: first, quality of production is often ignored when quantity of production becomes urgent; second, understanding of the importance of quality has not penetrated much beyond management circles. Quality incidence changes in cycles. After managers stress on the importance of quality, then workers begin to pay more attention and quality becomes good. However, it usually declines bit by bit along the time, until, when it reaches 'red line', the managers have to 'sound the alarm' again (The director of the Department of Productivity & Quality Management, 9.11.1992).

System 12 was developed in industrialised countries. No matter how experienced the developers were, some problems were inevitable in applying the technology in China. On top of that, when the technology was first introduced into China in the early 1980s, System 12 technology *per se* was still immature.[16]

Some problems were obvious. For example, System 12 uses English as a human-machine communicating language, and all the technical documents and the kernel and common application software were written in English. In the documentation transfer alone, "several hundred thousand documents" had to be translated into Chinese (Zhou and Kerkhofs, 1987: p.191). Moreover, many posts using the computer required operators who could understand English. For candidates applying for a job in Shanghai Bell, in most cases, one special requirement was English language comprehension. Further there was a compulsory requirement for new recruits to undertake certain English courses to reach the firm-specified level.

Another related problem was technical training for customers. As a normal requirement, to operate System 12 needs special technical training for customers. In the case of Shanghai Bell, it had to add the teaching of the technical terminology in English to training. In the early stage, Shanghai Bell's technical training courses used BTM's text book which had been translated into Chinese. Because it was a (poor)

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[16] The first System 12 exchange in use anywhere in the world was in June 1986 in the Netherlands. It was only six month before the first Shanghai Bell-made System 12 was put into operation in China.

translation, the book was so difficult to read, that, as the manager of the Training Centre described:

> Those who could easily understand the technology avoided reading this book, whereas those who would read this book in order to understand the technology did not get any help from this reading (Manager of the Training Centre, 29.1.1993).

When System 12 was installed in large or middle sized cities, it was not difficult to get reasonably educated people who had learned more or less English. These people, after taking technical training courses in Shanghai Bell, could undertake the operation posts. However, as System 12's market share were expanding and some exchanges came to be installed in small towns or villages, it became very difficult to find suitable candidates for even the technical training course, who could, at least, understand English.[17]

Irritations also came from using imported equipment and machines. All machinery and equipment used for exchange production in Shanghai Bell were specified by BTM, including the brand and/or producer. Problems arose with their maintenance and spare parts supply, because most of them were imported from abroad - apart from a few produced in joint ventures in China. For example, the surface mounting technology was fairly advanced technology in production of printed circuits. Shanghai Bell bought this British made machine at a cost of $200,000.[18] However, since its installation, the machine broke down often, and Shanghai Bell couldn't get it repaired in time. Chinese engineers tried to make the broken parts by themselves. However, because they lacked the proper material, locally made parts wore out easily, making the machine break down more often. The inserting machine provided by Universal, which was supposed to work continuously, broke down approximately every twenty hours. Since Universal had already set up a joint venture manufacturing the same machine in China, spare part supply was much easier.[19]

In the early stage, one of the biggest problems for the System 12 technology was the condition of the Chinese telecommunications network, which was poor in general and

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[17] Those with such a degree of education could have better jobs than being a phone operator in these places.
[18] According to my discussion with shop-floor engineers and workers in Shanghai Bell's workshop, 1.3.1993.
[19] Ibid.

uneven over the country, in terms of facilities and equipment. For instance, transmission lines varied from bare open wire in remote districts to fibre optic cable. As a result, signalling conditions differed from place to place and changed from time to time depending on weather. Different generations of exchange technology were operating in the same network, ranging from manual exchange, early step-by-step, Strowger, and cross-bar electric-mechanical exchanges to advanced digital switching systems. Moreover, when the first Shanghai Bell system was installed in the Chinese network, even the signalling systems used in the network differed between exchanges. System 12 was a sophisticated technology, designed with a presumption of high transmission quality. In the very different rough conditions of the Chinese network, System 12 often failed to identify correctly the different kinds of signal.

During the first few years of operation, Shanghai Bell encountered acute problems, both technical and financial. Serious technical problems occurred on installation because the technology itself was immature and because BTM experts were not familiar with the Chinese telecommunications environment. Interrelated with this, there was a financial crisis. During the early stage of technology transfer, Shanghai Bell was only assembling piece parts imported from BTM. However, the price of these piece parts was high, with the result that the total cost of assembled exchanges was higher than directly importing finished exchanges. To make matters worse, Japanese companies were offering their exchanges at a lower price. At that time, Shanghai Bell's System 12 cost $250 per line, compared to $150 per line on average for the Japanese systems.[20] Shanghai Bell barely got any orders from the domestic market.

During this period of time, the production volume was very low: 66,000 lines in 1986, which fell further to 15,000 in 1987 (Shanghai Bell, 1992). The company was running at a loss. Between the 1984 inauguration of production and 1987, Shanghai Bell had run up a total debt of $15,000,000.[21] Shanghai Bell was not able to pay fees for technology transfer, and even felt hard pushed to pay the Belgian engineers' salaries. At the same time, BTM was unhappy and threatened to stop the transfer.

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[20] Interview with the vice-chief engineer in Shanghai Telephone Administrations, 10.2.1993.
[21] Interview with a deputy manager of Personnel Department, 3.11.1992.

In this situation, MPT adopted strong measures to attract customers. Users buying Shanghai Bell's System 12 could receive an MPT subsidy of $30 per line. In total, MPT provided 60,000,000 yuan RMB (equivalent to around $17,000,000) in subsidy.[22] With this support, Shanghai Bell regained its momentum. In 1988, it recovered and produced 189,000 lines. That year was the first year of profit for Shanghai Bell. After the 1989 Tiananmen debacle, foreign government soft loans were greatly reduced, and the domestic political situation drove the market towards locally produced systems. Ever since, Shanghai Bell's production has been rapidly increasing, and its position in China was privileged in many respects.

As a joint production venture, Shanghai Bell was allowed to pay much less tax than domestic companies,.[23] Shanghai Bell was free of tax for the first couple of years, and tax charges were deducted by 50% in the following few years. After this, as it was classified as a high-tech company, tax reductions were still applied.[24] In addition, the state granted a license for Shanghai Bell to import component at a low tariff rate (section 5.5.2). Shanghai Bell was given the right to purchase components directly from overseas and, moreover, allowed to collect a certain portion of its payments from Chinese customers in foreign currencies.[25] A joint venture like Shanghai Bell was also given management autonomy to decide the internal organisational structures and material rewards.

MPT gave considerable attention to Shanghai Bell's creation, resource allocation and the market for System 12. From the outset, it set up a dedicated bureau in Shanghai to co-ordinate with local government on the building of Shanghai Bell's factory. To ensure its domestic market, MPT decreed in an internal circular[26] that System-12 was

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[22] Figures provided by a deputy manager of Department of Operational Finance at PTIC.

[23] According to *The Law of the People's Republic of China on Joint Ventures Using Chinese and Foreign Investment*, Article 7, "a joint venture equipped with up-to-date technology by world standards may apply for a reduction of or exemption from income tax for the first two to three profit-making years". This law was adopted on July 1, 1979 at the Second Session of the Fifth National People's Congress; Promulgated on July 8, 1979. (Shanghai Municipal Foreign Trade and Economic Committee, 1985)

[24] Interview with the deputy manager of Department of Operational Finance at PTIC.

[25] Domestic enterprises did not have such rights. (see more detailed description in chapter 6)

[26] Interview with the vice chief engineer in Shanghai Local Telecommunications Administration and was confirmed in other interviews in Shanghai Bell. I did not see the internal circular. However, there is the State Council No. 56 dispatch in 1989 which indicated clearly, "it is requested for all purchasing of foreign switching systems to use the ones which have already been selected by the government". (The Telecommunications Administration Bureau at Zhejiang Provincial Posts and Telecommunications Administration, 8.1992, p.93)

one of the principal switching systems for use in the Chinese telecommunications networks. MPT also endeavoured to obtain funds and loans required by Shanghai Bell from relevant government departments.

In terms of human resources, at the end of 1983, MPT brought together a group of highly skilled staff from MPT's R&D institutes, universities and factories across the country to Shanghai Bell to set up the plant. Among them were many experienced senior engineers, and knowledgeable professors in telecommunications field. They played a crucial role in building up the company in the early stage. Thereafter, most of them returned to their institutes, and some subsequently used the knowledge they had obtained of System 12 to carry out various R&D projects for Shanghai Bell. In October 1985, when the first production assembly was to be put into operation in Shanghai Bell, MPT again took the role in recruiting capable graduates and experienced young engineers all over the country to join the work force. Many of them, later on, became departmental directors, and section managers and formed the technical nucleus of the company.[27]

As a joint venture located in Shanghai, Shanghai Bell had received substantial support from the Shanghai Municipal Government. In particular in the early stage of constructing the joint venture, Shanghai Municipal Government helped the company in obtaining required resources within its territory, from electric power supply to new work-force recruitment. As Shanghai Bell was regarded as a source of advanced technologies for the region, it was even better treated than its state-owned counterparts by the government. In May 1991, with the Shanghai government nomination, Shanghai Bell was conferred the title as one of the Top Ten Joint Venture Companies in China. In June of the same year, the Shanghai Municipal Government awarded the Shanghai Bell's Belgian director the "Magnolia Medal" - a high honour paid by the city.

As mentioned in chapter 4, following the Cultural Revolution, China was short of almost everything. Shanghai, one of the biggest industrial bases and the commercial

[27] Many of the young managers I interviewed in Shanghai Bell belonged to this batch of recruits, which was arranged by MPT.

centre of country, suffered from shortages of electricity power supply, water, housing, etc. For many local manufacturing companies, power cuts occurred for several hours almost every day, especially in summer at "peak-hours". However, because of the particular concerns of the local government, Shanghai Bell was able to avoid this problem from which other companies suffered badly. The harsh conditions facing other companies was expressed by a non-Shanghai Bell engineer:

> The power supply in our factory has been often cut off, sometimes we were notified beforehand, sometimes not even this. Frequent cut-offs in power supply causes unstable temperature of the soldering torch and therefore often causes quality problems, as well as low productivity. In summer, when the power supply gets worse, even air-conditioning in the workshops was restricted to only several hours a day. You can imagine, how awful it is to stay in a workshop with natural temperature at 35 - 38 centigrade for eight hours, not to mention working with soldering (A non Shanghai Bell engineer in workshop, 2.2.1993).

As noted in chapter 4, under central planning, human resources were arranged by the government. This was based on the regulation requiring registration of residence. In other words, people were not mobile unless there was government approval, e.g. because of their particular level of education and/or occupation. Because Shanghai was already an overcrowded city, Shanghai enterprises could only employ Shanghai residents. Any other new recruitment had first to be approved by the municipal government. During the first ten years of economic reform, these regulations were still effective. In the case of Shanghai Bell, which had recruited manpower from all over the country, the Shanghai government always gave a green light to this.

5.4 Assimilation of the Foreign Technology

After the first stage of technology transfer when Shanghai Bell tried hard to master the technology as a whole, Shanghai Bell realised that it could not simply copy these technologies but that it had to adapt them to the Chinese environment. This section tells how Shanghai Bell, in the face of difficulties, gradually mastered more and more of the technology and were able to work better on not only System 12 *per se* but also on production process technologies. In particular, as a joint venture having a special position in China during the transition period, Shanghai Bell had learned to take advantage of its connections with its locality and the Chinese government as well as overseas to strengthen its capabilities in marketing, sourcing and management. At the same time, while enjoying support and protection from the government, it made efforts not to fall into the rut that state-owned companies found themselves.

In this section, there are five sub-sections, which respectively examine: the adaptation of System 12 product to Chinese telecommunications environment (5.4.1); the adaptation of the production process (5.4.2); the accumulation of marketing capabilities (5.4.3); the accumulation of sourcing capabilities (5.4.4); and the combination of Chinese and Western management methods (5.4.5). The last three subsections are very much related to how Shanghai Bell, based on the Western business values of efficiency and productivity, pursued its market share, secured its human, financial and technology resources and sought a high performance from its workforce.

5.4.1 Adapting System 12 to Chinese Environment

System 12 software consists of several layers. The generic system kernel is the basic layer which is common to all System 12 applications in all countries, providing the operating system, database, input/output and system maintenance functions. In addition, there are the application layers. Some application software was specially designed for the system to meet country-specific requirements (e.g. CDE), some is needed to fit the switching requirements of particular customers (e.g. CAE). If System 12 is applied in a country where telecommunications technology is largely internationally standardised, then its application related software has a higher degree of commonality. As already described in 5.3.2, China had very complex conditions, and its technologies in public network were far from the international standards. Therefore, to ensure the success of System 12, a proper adaptation of this system to the Chinese telecommunications environment was essential.

However, this adaptation took time. It did not happen in Shanghai Bell straight away. Rather it arose through a gradual learning process, which included growing demand from the market. As the Chinese general manager described:

> In the first instance, we had technical problems. However, we did not quite understand the system and were not able to change the slightest detail of the products. That time we had to rely on the Belgian Engineers. Now, we

> understand more and more about the technology and begin to do a few changes here and there with help from experts. We do this and are allowed to do this, because of our customers' needs. However we cannot do much as we are still learning; besides, these changes need BTM's approval (Chinese general manager, 1.2.1993).

As mentioned above, the transmission conditions in the Chinese networks made it difficult for the exchange to identify signals. For this, Shanghai Bell developed supplementary instruments to monitor and identify the condition of the transmission lines. This was done with the help of local universities and R&D institutes.

With the continual development of the country's telecommunications infrastructure, the regulations and specifications for the networks and services had also been modified. To integrate System 12 with the country's specifications, Shanghai Bell from the outset set up a task force to update CDE. According to the previous agreement between BTM and PTIC, CDE projects would mainly be performed by BTM engineers, and only a few Chinese engineers in Shanghai Bell would be selected to participate, as this task requires deep understanding of the system. However, as it turned out the Chinese team undertook 80% of the CDE software development work compared to 20% by BTM mainly in the form of supervision and consultancy.

At the same time, MPT and Shanghai Bell established a working group, named the Communal Co-ordination Group (CCG). Its major task was jointly to set targets for System 12 technology innovation in line with the development of the telecommunications network. In particular, this sought agreement on CDE innovation between MPT (which was both user and administration) and Shanghai Bell (supplier). CCG organised working seminars involving a deputy minister of MPT as the chair, and many senior engineers and senior research fellows from various MPT R&D institutes, and key officials from relevant MPT's administrative organisations to discuss the issues. A successful result was the CDE software package-5X, which involved more than 30 person-years by the time of its completion. At the end of 1992, the first toll exchange equipped with the package-5X was put into operation in Shanghai. With the CDE package-5X, which integrated the MPT's specifications that were compatible with new CCITT regulations, the exchange was able to provide many new features for advanced services. In February 1993, the fourth CCG meeting was held in Shanghai, with up to 80 participants, to discuss further targets for the new version of System 12 NGLT - release 7. The new CDE project was to be completed by the end of 1994 in time for the expansion of Shanghai Bell's production in the second half of 1995.[28]

To meet a wider range of customers' demand, Shanghai Bell developed a remote autonomous switching module (RASM) with a capacity of about 1000 lines, which suits rural areas where population densities are low, and was also for engineering teams working in areas without existing telecommunications networks. The technology was designed by several Chinese engineers and was patented in August 1990. It proved to be welcome by users, since China has a large rural area where people could not afford the expense of System 12 to this date.[29]

However, there were differences of opinion within Shanghai Bell about whether it was necessary for Shanghai Bell to master every single technology of System 12. Almost all the young Chinese managers believed that the most important issue was the profitability of the company: they thus saw the need for technological capabilities solely in terms of the ability to adapt System 12 to satisfying user requirements, and strengthen Shanghai Bell's position in the market. They argued:

> Just as China is a 'tree' in 'the world national forest', so Shanghai Bell can play a part amongst all System 12 producers in the world. The relationship we prefer is technological complementarity between one another, each with its own particular strengths. Now we, Shanghai Bell, can produce the best software and tapes for Chinese market, and one day we will achieve more (the Deputy Director of Engineering Department, 10.11.1992).

In contrast, many older engineers had different views. They hoped that Shanghai Bell would build up its own strong R&D base, and could undertake the development work independently, anticipating the eventuality that the supply from overseas might be cut off.

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[28] About the CCG group, the deputy director of engineering department provided most details at the interview, 30.1.1993.

[29] Details of RASM from interview with the deputy director of Engineering Department, 30.1.1993.

5.4.2 Adapting Production Process

As mentioned in section 5.2.2, in manufacturing System 12, Shanghai Bell introduced the latest production facilities and production processes. Over time, these production technologies were updated in line with BTM's technological innovation. Although these technologies were at the world level, e.g. in 1992 the surface mounting technology was the most advanced technology in circuit production in the world, they were still foreign technologies which Shanghai Bell depended on. In other words, Shanghai Bell always had to follow BTM and transfer the technologies which are adopted by BTM in order to upgrade its technology. The deputy manager of the Operation Department (production) described the situation:

> We are still at the level of 'copying' in terms of production technology, including the production process, production organisation and techniques. When BTM has any technological change, we copy it. The equipment we are using, its types, producers, and variables, are decided by BTM. That was the agreement between BTM and us. Even if we want to use a more advanced machine, we have to get BTM's approval (The deputy manager of Operation Department, 6.11.1992)

Nevertheless, there were some technical achievements that Shanghai Bell was proud of. As mentioned in section 5.2.2, for economic reasons Shanghai Bell did not transfer some technologies, which were not considered to be the core of the production process. In the early production stage, their functions were undertaken by manual labour. With the growth in production, Shanghai Bell developed some of this ancillary production equipment in co-operation with local universities and R&D institutes. One example was the automatic test apparatus for checking the DC-AC converting board.

The development that Shanghai Bell was most proud of was a new set of CAE. This set of software tools was used for running an automatic production process transferring the specifications of each application onto programmed data tapes which were then loaded into the production system to produce individual exchanges. In the beginning, Shanghai Bell used the CAE which had been developed by BTM, which did not work very well in practice. Chinese engineers in Shanghai Bell therefore gradually modified the software package: they began by adding a patch to the package, and then another one. Over time, their understanding of the software package also developed. When the number of the patches grew substantially, over

300, they rewrote the whole package. It proved to be simple to use and very effective and involving fewer problems.

Although this set of software tools was aimed to improve production by Shanghai Bell itself, it came to attract the attention of other System 12 producers. The first buyer to come to the door was SESA (the System 12 producer in Spain). It was turned down by Shanghai Bell. SESA turned to its sister company - BTM for help. BTM did send engineers to Spain to help improve its existing CAE software, but the result turned out to be not as good as Shanghai Bell's. At the end of 1992, SESA came back to Shanghai Bell, and eventually made a deal that Shanghai Bell would sell the software package to SESA and in return SESA would provide Shanghai Bell with $1.8 millions of business per year over five years.[30] Shanghai Bell was very proud of this success. Both the Chinese general manager and the Belgian general manager declared that Shanghai Bell was able to provide the best application software for the Chinese market.[31]

For BTM, Shanghai Bell had gradually become a technically reliable partner. When BTM's customers in China needed technical assistance, it often asked Shanghai Bell to send engineers to solve problems. Once its international exchange (trunk)[32] in Beijing needed a capacity extension, and some new functions to be added. As BTM was short-staffed, it turned again to Shanghai Bell for help. Despite the fact that the Chinese engineer had never done any international exchange work, the mission was successful.[33]

5.4.3 Accumulating Marketing Capabilities

In the Chinese PDSS market, demand was huge and always exceeded supply. By the end of 1992, orders taken by Shanghai Bell were already queued up to 1994. Shanghai Bell's share in the Chinese PDSS market already exceeded 50%. Its

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[30] This material was provided by the deputy manager in the engineering department at the interview on 30.1.1993.
[31] Interview with the Belgian general manager of Shanghai Bell, 10.2.1993 and the Chinese general manager, 1.2.1993.
[32] Which is technically more complicated than the exchanges used for telecommunications switching within the country.
[33] Interview with the deputy manager of Engineering Department.

products had covered almost all the provinces of the country. Despite this, Shanghai Bell sought to ensure its future market. While increasing the scale of production, it gradually brought down the price. Compared to $250 per line in 1984, the price of the exchange was reduced by 50-60% in 1992.[34] Apart from that, Shanghai Bell's marketing strategy was to rapidly cover as many districts of the country as possible with its products. This was because they knew that once they had installed the first exchange of a region it would often lead to further purchases later on, for reasons either of technical continuity or of economics. For example, noting that Tibet area did not have any System 12 exchanges, Shanghai Bell offered them one for free.

Over time, Shanghai Bell's installation team became more and more experienced, and its work force was meanwhile expanding. Compared to the first installation of Shanghai Bell's System 12 which took about a year, the current set up time for an exchange, from hardware and software installation to system debugging and to final cutting-over, needed only about a month. The quality of installation also improved. As the production capacity of Shanghai Bell expanded rapidly, the activities of the installation team increased dramatically. In 1992, it installed around 318 exchanges - nearly one exchange per day.[35] To meet the demands, Shanghai Bell used fully its connections in the sector. It hired several MPT engineering teams to carry out installation works in neighbouring areas which they were familiar with. It also used engineers who had been technically trained in Shanghai Bell (for more details see section 5.5.1) to carry out a relatively difficult job in installation - software testing. This measure proved to be economical for Shanghai Bell, as well as effective.

To provide adequate after-sale-services, Shanghai Bell had built up a number of maintenance centres, in Beijing, Shanghai, Hefei, Guangdong and Shandong, (by the time of my visit) and was planning to set up more in all 29 provinces and autonomous administrative districts of the country. Apart from that Shanghai Bell's computer centre had been providing 24-hours services for users, it also established the Customer Association with members across the country. Every six-months, it invited users to a meeting to give feedback on using Shanghai Bell's products. The meeting in

[34] Interview with the Manager of Marketing Department, 28.2.1993.
[35] According to the deputy manager of Engineering Department, Luo Wei, who was in charge of installation.

April 1992, for instance, gathered over four hundred users. Shanghai Bell also arranged a "System 12 Column" with two pages in a telecommunications journal - *Telecommunications Technology* - whereby Shanghai Bell regularly introduced the system to users and discussed trouble-shooting experiences. In addition, Shanghai Bell circulated widely an occasional publication named "Bell Dispatches", the first edition of which was published in 1992. Along side this, in its user's computer network, it ran an "information" system which collected a large number of issues on the utilisation of System 12. Some essays were instructions written by specialists and others were engineers' experiences; all were carefully classified to allow users to search easily on-line. Taking advantage of MPT's traditional arrangement, involving the development of a couple of highly experienced engineers in each district, Shanghai Bell co-operated with them to solve technical problems on-the-spot.

In line with general Chinese government policy, Shanghai Bell was encouraged to export its products. However, because of the pressing demand for PDSS in domestic market, Shanghai Bell's exports were very limited. A few System 12 exchanges were exported to Russia, Vietnam and Cuba. More widespread export of System 12 by Shanghai Bell would have been against Alcatel's interests, as the Belgian general manager noted:

> It is common knowledge that, through technology transfer, the technology supplier wants to create markets rather than create competitors. I think, if Shanghai Bell attempts export, the process of technology transfer will be slowed down by the Alcatel side. Obviously, Alcatel doesn't want to have a rival who is as strong as itself in technology (Mr. De Graeve, 10.2.1993).

On the other hand, Shanghai Bell had achieved high value-added exports of system-load-tapes and their CAE software tool package which were attractive to other System 12 producers which had sold or were going to sell System 12 in the Chinese market. These producers included SESA (Spain), BTM (Belgian) and SEL (Germany). Other System 12 producers from Norway, Italy and Australia were still in the process of negotiation with Shanghai Bell at the time of the fieldwork.

5.4.4 Accumulating Sourcing Capabilities

With the expansion in production capacity by Shanghai Bell, more human resources were required. Learning lessons from state-owned companies, Shanghai Bell sought to recruit young graduates. Every year, it enroled selectively a certain number of graduates from universities and colleges. Moreover, in the recruitment of manual workers, Shanghai Bell took a very cautious stance to avoid creating a possible labour surplus in the future. Instead of recruiting permanent staff, it "borrowed" a large number of labourers from other companies which were economically stagnant and suffered a burden of labour surplus. In this way, Shanghai Bell had, on the one hand, avoided an excessive increase of labour force, which might become burdensome to it for example in requiring provision of long term welfare facilities, and on the other hand, solved the current problem for both Shanghai Bell itself and the companies which had a labour surplus.

By the end of 1992, the number of enlisted employees in Shanghai Bell was 1,313, and the average age was 28.6 years old. There were also over 300 labourers who had been temporarily transferred from the other factories and institutes.[36] Most of them were low-skilled workers. They received the basic salary from their original companies, which was a relatively smaller portion of their income, compared to the bonus that Shanghai Bell gave them. Although their average income was less than that of Shanghai Bell's employment, it was still much more than what they previously received.

Shanghai Bell also managed to get many highly skilled external "workers" working for the company. They were all engineers sent by customers to Shanghai Bell. By agreement between Shanghai Bell and its customers, after their 6 months training courses, these engineers would continue their further practice in Shanghai Bell for 1.5 to 2 years. As a result, given these previous experiences in the field and these newly acquired knowledge about System 12, they were very capable indeed. They played an important role in helping Shanghai Bell to install and maintain System 12 in the field

[36] Interview with Manager of personnel Planning & Education at Personnel & Administration Department 3.11.1992

as already mentioned. The benefits of this arrangement were mutual. Most of these engineers were happy to work for Shanghai Bell at that time. On the one hand, with their salary from their own company plus the portion Shanghai Bell provided on top, their income became much higher than usual, and, on the other hand, working with Shanghai Bell, they could acquire new expertise.

Shanghai Bell's policy was to use external human resources as fully as possible in order to keep the company's complement of staff at a low level. In terms of R&D, Shanghai Bell co-operated with local universities and research institutes. In installation and maintenance, it sought help from MPT engineering teams and experienced engineers in local PTAs. It hired local professionals to provide other logistic services, such as providing food and medical service to its staff rather than establish its own hospitals and canteens. Through this policy, Shanghai Bell's employment only increased by 54% from 855 in 1989 to 1,313 in 1992, compared to a 317% increase in its production capacity during the same time.

The Chinese general manager's joke told the truth, - that Shanghai Bell had been a "big school", fostering a great number of qualified engineers for the country. Every year, around 3 to 4 percent of the engineers left the company to work elsewhere, whilst more new ones joined. Among those who left Shanghai Bell were many good engineers. As the deputy manager of the Engineering Department (himself 28 years old) said, "they are good enough to find good jobs elsewhere easily".[37] For example, when Motorora established a new joint venture in Shanghai, it recruited three senior engineers, two of which were from Shanghai Bell. Some went even further to join a local PTT in Australia. Although, for Shanghai Bell, this was still far from a threat to the company, as it could always find proper candidates to fill the vacancy, top managers were convinced that there were something the company should do to keep these capable engineers.

Apart from providing material incentives, such as high salaries and relatively luxurious housing conditions, top managers gradually realised that material incentives were not everything, but that job satisfaction was also important. At that time, some newly

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[37] Interview 31.1.1993.

established joint ventures and private companies were offering much higher salaries to get the manpower they needed. However, Shanghai Bell for reasons we discuss below, was not able to respond in this way. The problem was that there were too many capable young engineers in Shanghai Bell, but there were not enough interesting jobs for them. For these capable young engineers, routine work in the production field was too repetitive, and most job posts required little creative instinct. To fully use these young people's talents, as well as to keep them there and not join Shanghai Bell's rival companies, the Chinese general manager was planning to set up some R&D projects allowing them to devote their energy to projects which would also be useful for System 12 production, installation and services.[38]

A joint venture like Shanghai Bell attracted enormous government attention. Its managers, and in particular Chinese managers, who understood the importance of this connection, had learned how to utilise the government's concern. While the Belgian managers found the government intervention irritating, Chinese managers seemed to be more relaxed about it. For example, Shanghai Bell's annual production volume was usually decided jointly by BTM and the Chinese government through their representatives on Shanghai Bell's Board of Directors. In 1992 soon after the time for both sides to work out the production volume for 1993, and the Board of Directors decided that the year's production volume was to be 1,500,000 lines, a new message came through from the Chinese government indicating that production volume should increase greatly. The State Planning Committee proposed a number as high as 2,200,000 lines, and MPT pushed this even further and made the figure 2,700,000 lines. The Belgian side was irritated, and also thought this attempt was incredible. However Shanghai Bell's Chinese top managers reacted differently. Soon, they went to find out the reasons for this recommendation and decided that fulfilling it would be also good for Shanghai Bell. First, from the Chinese government's point of view, at that time, it had already become inevitable to open domestic PDSS market for the USA. To ensure Shanghai Bell's position in the market, the government wanted Shanghai Bell to expand its market share as far and as quickly as possible. This coincided with Shanghai Bell's interests for the long term development. Second, now

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[38] Interview with the Chinese general manager 1.2.1993.

that the State Planning Committee had given this quota, it gave Shanghai Bell the possibility of low import tariff of components needed to produce 2,200,000 lines. Shanghai Bell therefore accepted this figure and moreover, reached this level of production in 1993.

Apart from taking advantage of the Chinese government's support, Shanghai Bell was also able to use fully its technical resources overseas. By 1993, many System 12 components could be purchased locally. Nevertheless, Shanghai Bell still continued to import a portion of these components, even though this irritated the Custom Office. Shanghai Bell had a particular purpose for this - to keep open its links to technological changes in the world. As the deputy manager of the Department of Engineering explained:

> I have to say that, in terms of technology, the core technology of System 12 is still not in our hands. The future of System 12 depends more or less on technological development in the industrialised world. We do not want to drive foreign suppliers away. Rather we want to be kept informed by their product changes. Although we have to pay more, compared to purchase local products, we would like to keep the pace with the world (Deputy manager of Engineering Department, 30.2.1993).

5.4.5 Mixed Style of Management

At the outset, the management in Shanghai Bell was to copy BTM. Later Shanghai Bell gradually developed its own style which was considered to be a hybrid between Chinese and Western methods. In the very beginning, the Chinese decided to adopt Western management approaches, in particular those of BTM, in terms of its institutional settings and managerial methods. For this purpose, some young Chinese managers were sent to BTM and other Management Schools in China and abroad to learn advanced modern management theories and methods. However, very soon, practice proved that it was impossible to apply many Western methods to the Chinese environment. Inevitably, the outcome of adapting Western management method to the Chinese environment was a mixture of both. Western methods dealt with question of productivity and efficiency whereas the Chinese way dealt with incentives of staff.

First of all the objectives of company was market growth and achieving profits. Shanghai Bell's management had been concentrating on this target, with the result that it had achieved a high level of productivity. In 1992, the production output was 1,380,000 lines, with only 800 workers. Accordingly when production volumes reached 4,000,000 lines after the completion of a new workshop in the end 1994, Shanghai Bell planned to keep the number of worders as low as 1,400, compared to the BTM's estimate of, at least, 1,650.[39] Although there were political organisations in the company, such as the Communist Party, Trade Unions, the Youth League and Women's Association, their importance had already given way to productivity: their organisational activities only took place after work; and they took up only the smallest fraction of the company's agenda, compared to state-owned companies, where the Party's activities were always given high priority.

Material incentives were explicitly adopted, as already noted. In comparison with state-owned companies, Shanghai Bell offered much higher salaries, although the salary level was still far from the highest in the Shanghai area. As an early established joint venture, Shanghai Bell was allowed to raise the salary level for its employees only by up to 30 percent above the average of state-owned companies. This was set by the government in order not to provoke workers in state-owned companies, especially in MPT's companies. Over time, as more and more joint ventures and private companies had been set up and started to compete with each other in offering high salaries, the average salary had increased rapidly. Shanghai Bell, as a large company was simply not able to follow the pace. In 1992 it raised its general salary levels, but very soon, the other companies caught up and overtook it.

To compensate for this, Shanghai Bell provided employees with housing.[40] It spent 50% of the company's total welfare expenditure on housing for staff. By the end of 1992, about 10% of its employees lived in company flats. The flats which were provided for key persons, such as, department managers and senior engineers, were fully furnished, and some were even equipped with all household electrical appliances. For ordinary Shanghai residents, it was just paradise and could not be better. One department manager, a flat-holder said:

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[39] Interview with the Deputy Manager of Operation Department, on 6.11.1992.

[40] Housing in Shanghai was extremely scarce, as in a popular saying it vividly described that, "It is easier to find a wife than a flat".

I won't expect any better than this, and I think that our company's offer is the best in the whole Shanghai area, although our salary is a bit low (Deputy Director of the Engineering Department, 30.2.1993).

A condition attached to this offer was that, if one leaves Shanghai Bell, then one should leave the flat too.[41]

Chinese management traditions tended to treat the company as it was a family. Its administration system was fairly hierarchical, but the relationship between the upper and the lower was not necessarily very formal. The authority of a director of the company could be very much parent-like. Even a manual labourer at the lowest level was encouraged to approach directors or higher level managers of the company for help with personal problems, even bypassing intermediate management. In this respect, Shanghai Bell still kept the old tradition. A department manager explained:

People still turn to us for help when problems occur with their family, things like that a child was ill or couples have a row, etc. Although these are now not considered to be our responsibilities according to the job specification. However, we have got used to it. The company takes care of them, and they take care of the company (Deputy Director of Engineering Department, 30.1.1993).

The Chinese general manager of Shanghai Bell believed the combination of Chinese and Western management method was necessary and said:

Working for foreign companies will make you feel that you are only working for the company which belongs to strangers. But in our company you still feel you are working with people who belong to your 'family', having a feeling of part and sharing. When a member of staff has got a problem, he or she can approach me directly, either with or without an appointment, in working or non-working time, as long as I have got time. This is Chinese culture. Although Western management provides us with efficiency in production organisation, we still need staff who are devoted to hard working. The fact that we, Shanghai Bell, could achieve such a production expansion, has to be attributed to the combination of Chinese and Western management (The Chinese general manager, Li Dalai, 1.2.1993).

Belgian managers were very sympathetic to their Chinese counterparts, believing that they must be exhausted dealing endlessly with problems, such aswages, housing and so on, which they themselves could not have stood. They were happy with the division of management responsibilities, whether explicit or implicit, that the Belgian

[41] The Manager of Personnel Planning & Education at Personnel & Administration Department, Shanghai Bell provided me with the details about material incentives which Shanghai Bell provided to its staff.

managers would concentrate on production and leave personnel issues altogether to Chinese managers.

5.5 Technological Learning

Technological learning in Shanghai Bell had taken place throughout the whole process of System 12 technology transfer. This section in particular looks at the learning activities planned and organised by Shanghai Bell, as well as the Chinese government and Shanghai municipal government. The major focuses are: technical training courses which were run by Shanghai Bell to educate its own staff and its customers; and the project of local production of System 12 components which was linked to Chinese government policies for technological development and was mainly organised by the Shanghai government to promote technology renewal in local industries. This section examines the successes and difficulties that arose with domestication of imported components, which related to the attitudes of local companies including Shanghai Bell, which had been changing during the period of China's social and economic transition.

The first sub-section (5.5.1) describes Shanghai Bell's technological training programmes for educating staff and customers. Section 5.5.2 explores the attempts at import substitution of System 12 components by Shanghai Bell and local industries, and section 5.5.3 explores the difficulties and successes encountered in this state-organised project, and then broader implications for government policies and macro environment of economic reforms.

5.5.1 Training[42]

Since the establishment of the joint venture, there had been a variety of training programmes in Shanghai Bell. In the beginning, engineering training programmes combined BTM's classroom training and participation in BTM operational departments, as well as training at the premises of the other technology suppliers in USA and Hong Kong. The engineers who were trained abroad, in turn, came back to

[42] The manager (Associate Professor) of the Training Centre provided the most detailed material.

initiate training courses in Shanghai Bell, transferring their acquired skills and knowledge to the others. Ever since, training whether technical or managerial had become an important part of the operating agenda of Shanghai Bell. As a result, according to a comparative survey in 1987, the performance abilities of the Chinese engineers in Shanghai Bell ranged from 70% up to as high as 100% percent of the performance abilities of BTM engineers in similar functions (Zhou and Kerkhofs, 1989).

From 1987, Shanghai Bell began to run a series of training programmes for both staff and customers. In 1991, it set up a training centre, which had been expanding rapidly because of demand.

Shanghai Bell introduced a new measure in staff training, that all new recruits had to be trained before taking any job post. The compulsory training for potential engineers was for six-months and three to four months for new shop-floor workers. In addition, every employee was encouraged to take after-work courses run by external training or educational organisations. For this, the company undertook 70% of tuition fees, provided the staff obtained "diplomas or certificates" at the end of their courses. With these diplomas or certificates, they could apply for a more suitable post in Shanghai Bell. Apart from that, because of the complexity of System 12 technology, people involved in one part of the work, did not necessarily know the others. In these circumstances, staff were encouraged to take training courses in order to get more knowledge about the context and how their jobs fitted in the whole system. As a result, the number of staff receiving training had been increasing over time. In 1993, the number increased to 160 person-years, compared with only 43 in 1989.

Shanghai Bell's philosophy on customer training was that the more people know about the system, the larger the market will be, the more maintenance work which can be carried out by users, and the less work will be left for Shanghai Bell itself. It therefore encouraged customers and potential customers to take training courses to learn System 12 technology. Shanghai Bell set up its customer training programme with three levels: "A" level training was for system engineers within 6 months including classroom and practical training; "B" level was for technicians, lasting three or four months; and "C" level was for operators, lasting only two to three months. The users were trained to carry out various jobs including test, installation, operation and maintenance. Especially, those engineers taking "A" level training would continue practice in Shanghai Bell. As noted above, usually, after this period of time working in Shanghai Bell, they would be able to deal with various problems independently. Some of them, later on, were even hired by SESA (the Spanish System 12 producer) which paid them a salary so high that, it did indeed, make Shanghai Bell's engineers jealous.

In 1987, Shanghai Bell could only carry out "C" level training, until 1990 when the three levels of training courses (A, B and C) were all set up. Since 1989, orders for System 12 had increased dramatically. Simultaneously, the number of customer receiving training increased too. By 1990, the number had reached 297, including 44 "A" level students, 42 "B" level and 211 "C" level, compared with only 102 students in 1987. Shanghai Bell therefore began to anticipate problems that might arise with the increasingly large scale of training in the foreseeable future. Usually, one exchange needs two operators working on each shift. Accordingly, for round the clock operation, there are at least six people who need to be trained. On average, one exchange has 2,500 lines. If Shanghai Bell's annual production volume was 1,380,000 lines like in 1992, the numbers needing training would be more than 3,300. Surely, Shanghai Bell could not deal with such a large training undertaking. As early as 1989, the company began to seek help from MPT's universities and technical high schools to run its customer training courses in their premises, using their teachers and facilities.

Apart from this, Shanghai Bell had set up a mobile training team which was equipped with a System 12 exchange in a container lorry. The team ran a range of intensive training courses for officials in local telecommunication administrations, and local sales-agents. The training courses last from 4 days to a month long. By February 1993, 1,216 people had been trained in this way.

As noted earlier, the BTM's teaching materials used by Shanghai Bell in the beginning proved to have many disadvantages. In addition, because the division of labour in Shanghai Bell changed over time, it had different job classifications from the original one that BTM used (BTM's job division was finer and more specialised than that of Shanghai Bell). It therefore became more problematic to use BTM's teaching text book. To overcome the problems, Shanghai Bell called several senior engineers together to edit a new set of textbooks for training courses. By the end of 1992, three of the four textbooks had been completed.

5.5.2 Domestication of Imported Components - Reacting to Government Intervention

As part of its technological development strategy, to ultimately achieve indigenous technological development of the country, in the 1980s, while more and more advanced technology transfer from industrialised countries took place, the Chinese government pursued vigorously its policy of import substitution. A range of related regulations and practical measures sought to compel companies to replace imported components with locally produced ones. For example, first of all, the government applied a high tariff to direct import of components. Second, to ensure that this policy would not drive away advanced foreign technology transfer to China, the Chinese government granted exemption or a low import tariff to individual projects which were considered to be in the national interests. Third, to pursue the spin-off of advanced foreign technologies, the government urged the companies which were using imported components to gradually reduce imports and replace them by locally produced ones. To help realise import substitution, government financial support was available for promising projects. The Ministry of Machine Building and Electronics Industry (MMEI) and the State Foreign Trade and Economic Co-operation Committee were jointly in change of controlling import licences, granting low import tariffs, setting up targets for import substitution and examining their implementation by companies.

The MMEI and the State Foreign Trade and Economic Co-operation granted licences for Shanghai Bell to import components at a low tariff. At the same time, they put pressure on Shanghai Bell to take action about the local production of components. They set up targets for import substitution for Shanghai Bell. The target for the first few years was 20% of total components, and gradually increasing to 70% by 1993.

Shanghai Bell's performance in this matter was regularly examined and linked to the renewal of their licences to import components.

Since achieving import substitution relied on not only Shanghai Bell, but also local industries and resources, government financial support, and etc., the issue was always negotiable. The government knew that there was no point in trying to force Shanghai Bell to buy local products which nobody in China could produce or which could not meet the quality criteria. Besides, there was even a specified method for measuring companies' achievement in import substitutions, which was internally issued in the end of 1987 by State Planning Committee. According to this formula,

$$\frac{\textit{Total cost of all components} - \textit{Total cost of imported components}}{\textit{Total cost of all components}} \textit{100\%},$$

individual items add different weight to the level of import substitution. The bigger the differential is between total costs at local price and the imported price of this item, the higher its contribution will be to the import substitution. Hence, the companies' choice of components for local production could lead to different results. However, variables in this formula can be interpreted differently. For instance, an "individual component" can be an assemblage of components. To count it as an item or break it down to details may have different results, because of price differences. A computer can be either counted as one item or many items; the price of a whole computer and the sum of the prices of its individual components are different.

It was Shanghai municipal government that actively pursued local production of System 12 components, as it considered Shanghai Bell to be a source of advanced technology to bring the local industries to a new level. In 1988, it adopted the Shanghai Bell's System 12 Project as one of the fourteen "Major Projects for District Development". The new Shanghai Mayor[43] even came to visit Shanghai Bell on the second day of his arrival in his new post. The local government meantime established an office, named as Shanghai Bell System 12 Project Conducting Group. This organisation was jointly run by Shanghai Bell, the Municipal Electronic Equipment

[43] The mayor Zhu Rongji is the Vice Primer of the state council.

Bureau, the Municipal Economic Committee and the Municipal Planning Committee. The local production of components for Shanghai Bell's System 12 comprised 38 sub-projects. The major role of the Shanghai Bell-System 12 Project Conducting Group was to examine the feasibility of individual sub-projects, to raise funds for them and co-ordinate between Shanghai Bell and local companies which were considered as potential components producers. Financial support for this project from the State Planning Committee and the local government comprised grants of 10,000,000 yuan RMB (equivalent to about $2,860,000) as well as access to foreign currency loans (for which the Municipal governments could draw on a $150,000,000 US dollars reserve held by the Chinese government).[44] Shanghai Bell received a portion of this amount, 3,000,000 yuan (RMB), for R&D.

Shanghai Bell followed the government's instructions and set up the Domestication Division in the company to deal with local production of System 12 components. Although, in the early stage of production, due to various technical and financial difficulties, Shanghai Bell had very limited interest in this undertaking. However, subsequent developments made it give greater attention to conformity to governments requirements. Under this pressure, Shanghai Bell co-operated with the local government and actively engaged in the project of import substitution. To achieve the target of local production of components set by the Chinese government was not an easy task. In the late-1980s, China already possessed more than 100 electronic component assembly lines, but non of these could meet Shanghai Bell's standards. For exchange uses, components have to be functionally very stable and durable. To meet this criteria required not only technology and finance, but also technological support from BTM and increased technological capabilities of local producers (which was, after all, the government's motive in building up these capabilities).

BTM did not oppose the project of producing System 12's components locally. It was instead supportive, as it assumed this project would lead to cheaper component supplies for itself. BTM prepared all the documents required with technical details, (Shanghai Bell had to pay for these), sent specialists and engineers to inspect local

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[44] Interview with the deputy director of the Shanghai Bell-System 12 Project Conducting Group.

companies' production facilities, and help them to master the production technology,[45] as well as to help Shanghai Bell set up a test system for examining locally produced component.

More sceptical attitudes towards this project came from local industries, state-owned companies, which had relatively better production facilities and human resources, which would be System 12's potential component producers. During that period, the financial position of most state-owned companies in Shanghai was not so bad, as the economic reform had not yet stimulated them to desperately seek new technological opportunities. At the same time, they were still constrained by traditional approaches, relying on the state. As a result, they were happy to get involved in project as it was arranged by the local government and it allowed them to get extra money from the government for renewing facilities and technologies. However, they lacked the sense that they should take full responsibility for making products of sufficient quality for the customer.

Therefore, while things did not work out exactly as the central government had requested, an important role emerged for the Domestication Division of Shanghai Bell to deal with the government officials in charge. First of all, it drew up a tactical plan corresponding to the targets scheduled by the government in that period and to find the best way of calculating to show a higher import substitution rate. Its other functions were to write convincing reports for the government and often to negotiate with officials in charge in relevant government organisations, in particular those in the Customs Office. For example, in February 1993 (the time of my field work), Shanghai Bell had 200 lots of imported goods including over 700 different kind of components kept by the Customs Office at Shanghai airport, while the workshops in Shanghai Bell were waiting for the new supplies to come in. There was a dispute between the Customs Office and Shanghai Bell which was, as usual, over the import duty, and in particular about which import rate Shanghai Bell should pay according to its record of import substitution.

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[45] Interview with the head of the Domestication Division.

Things like this happened often, and the shortage of imported materials and components became one of Shanghai Bell's headaches. This above all irritated the Belgian managers, especially, after 1 January 1993 when the Chinese PDSS market was opened up under strong pressure from the US government. The tariff for importing whole system was merely 9% whereas for the components which Shanghai Bell needed it remained about 30%.[46] The Belgian general manager could not find any justification for this:

> We are manufacturing System 12 locally. Why do we have to pay higher duty for importing portions of the components required for local production. Shanghai Bell is a business organisation which has to compete with others in the market in terms of price and quality. We of course would like to buy locally produced components, which would involve less trouble. However, we cannot find proper products. One can not expect us to produce good quality and cheap products, while, at the same time, buying the components which are expensive and worse quality. It's just impossible! (Mr. De Graeve, the Belgian general manager of Shanghai Bell, 10.2.1993)

Most of young Chinese managers in Shanghai Bell did not believe that the import substitution policy was necessary - and in particular that the high pressure put on Shanghai Bell was necessary. They argued in favour of the market mechanism, "if buying them in would be cheaper and better quality, why we should insist on producing them locally?" A department manager said straight forwardly, "We should buy better quality and cheaper products from the market regardless of whether they are Chinese or overseas." Others agreed in principle that the import substitution policy was good for the country as well as for Shanghai Bell in the long run, as local production would make component supply much convenient. However, they felt that the government's intervention against them was too onerous, and it would not help very much to achieve the target.

Nevertheless, the government requirement of local production of components was not negligible. As a manager in the Operation Department described, "the cost of importing 1,500,000-line components is about 120,000,000 RMB. If the tariff could be reduced to 10%, it is a big deal for Shanghai Bell". The Chinese general manager of Shanghai Bell express the extremely pragmatic stance of the company:

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[46] This was according to the deputy manager of the Engineering Department.

> The Government has its view for the entire country, similarly we have ours. We are seeking profit for the company. However, the government policy changes, we will pursue our own goals. When government is pushing us to adopt import substitution, well, we will do it, as long as the interests of the company would not be compromised. We have our own programme. When the time comes, we are going to vigorously pursue local production of components, to establish a large local supplier network to strengthen our position (The Chinese general manager of Shanghai Bell, 1.2.1999).

The head of the Domestication Division hated the situation that she had to play calculating games with the government officials, "that is a waste of time and does nobody any good", she said. However, she valued the policy of local production of components in general:

> To get a local company to make quality products is hard work. It needs so much effort, and sometime we had to give up. Our local industries need to learn new technologies and most of all new concepts of production. They do need help. Without government policy, this process might take much longer. Nevertheless, when it succeeds, we all feel happy. Shanghai Bell can also benefit from that. Supply from abroad has many disadvantages, for example, transport. Once, we were waiting for a lot of chemical material, but it did not arrive till the workshop had run out of the material. Later on we were informed that the cargo ship with Shanghai Bell's articles on had sunk. Import substitution, as I believe, needs the initiatives from three sides: the government, local industries and us - Shanghai Bell. It is very difficult without one of them (The head of the Domestication Division, 28.2.1993).

5.5.3 Difficulties And Successes[47]

At the beginning, government intervention to achieve local production of System 12 components did not obtain strong support from local firms, so the outcome of the project was far less successful than expected. Some sub-projects were ultimately abandoned for various reasons. And some completed ones proved to be not very successful because of either the high cost of production or unsatisfactory quality.

System 12 had about 4,000 individual components in total, which could be classified into four groups: racks and sub-racks and printed circuit boards; nine types of large scale integrated circuits (LSI); circuit boards and tapes; and components such as hybrid circuit, relays and the others. By February 1993 at the time of my visit, there were 794 items, which were able to be locally produced. However, most of them were low technology components.

[47] The head of the Domestication Division at Shanghai Bell provided detailed materials in this section.

Several major factors had influenced the accomplishment of local production of components. First was the financial issue, relating to the dilemma - whether to select low or high technology projects. In most cases, local production of components with low technology involves low costs, whereas to produce high technology components locally was unlikely to be attainable by local companies given existing local technological capabilities and low levels of investment. Some projects require a large amount of capital investment, in order to introduce new assembly machinery, and/or to even transfer new technologies from abroad. For instance, the project for the relay production alone absorbed around $8,000,000. If selected projects all required expensive high technologies, only a very limited number of projects could be undertaken within the limit of available finance.

Apart from that, the uncertainties surrounding technological development, future markets, etc. made many projects less attractive to local producers and made people wary of making too large investments. According to the head of Domestication Division in Shanghai Bell, in some cases, local producers were not taking up the opportunities at all: some spent the project money but did not produce reasonable results; some even used the project money for other purposes, since they were doubtful that the final outcome of the projects would bring them a profit. To them, the future market was unpredictable, and, at that moment, demand for components from Shanghai Bell was not that large, and there were, as yet, no other customers for such products. Some projects had been abandoned before completion, as System 12 technology had been changing. It was difficult to anticipate whether one day some components would be no longer needed because of new technology. To take one example, the project to produce a specific resistor, which had already completed the R&D and sample production stages by Shanghai Radio Factory No. 1. It was terminated because of the lack of further financial investment for mass production. According to the government's original plan, a state bank would issue a loan to support the production. However, when the bank learned that Shanghai Bell might not need this resistor in future because of technical innovation, it withdrew its commitment to this project, determined that such a large sum of money would not be another untraceable loan lost in the state sector.

Second, problems often resulted from the weakness of the entire industry in production related technologies across the country. For example, the Ministry of Machine Building and Electronics Industry had a state-owned company manufacturing electronic components for national defence products. Since the demand from the national defence sector had been shrinking, the company was running at a loss. MMEI was very keen to get the company out of its financial problem, and determined that Shanghai Bell could be a suitable customer for its two products: transistor and TTL circuits. It therefore did not grant Shanghai Bell a low tariff for importing these two components, and indicated that there was a local company which was able to produce them. However, MMEI overlooked the fact that in China most defence companies which were considered to have capability to make high technology products were only able to produce small batches of samples to satisfy limited number of customers. These technological capabilities were not geared for commercial production. In particular, when this company was manufacturing products for the defence sector, it did not need to consider the cost very much. In addition, most products required were made in a small quantity which did not require mass production technologies. Obviously, if the company attempted to make products in high volumes in the same manner as with small batches, the production costs would be very high - so much so, that the price of these components was higher than the imported ones. Shanghai Bell therefore refused to buy these transistors and TTL circuits. This became a long time negotiating battle field between Shanghai Bell and MMEI.

Last, but not the least, were quality problems closely related to the weak production technology. It was a common phenomenon in the country, that sample products were usually fine, but the quality of mass produced products often was much lower (chapter 6). The head of Domestication Division described the confrontation between Shanghai Bell and local producers, saying:

> No matter whether high-tech or low-tech products, we have often had battles with local producers about quality, which often ended up with unpleasant feelings on both sides. They thought we were unreasonable hypocritical, and went to the municipal office to complain about that we did not like to use local products. Quality problem can be traced back to our socialist tradition: no market, no competition; users could only buy whatever producers made, and producers took this for granted. We understood the problems of local producers. However, we could not accept their products. We have our

> standards, which we have learned from BTM. Local producers have to face the challenge too (the head of Domestication Division, 28.2.1993, Shanghai).

As a very typical example, once Shanghai Bell was to buy a lot of screw, a commonly used product. It sent an order to a local screw producer and attached to the order with the technical specifications of the screw. However, when the lot of screws was delivered to Shanghai Bell, many unexpected problems were found. For example, the thread of the screw was not deep enough; the surface finish was not smooth enough, etc. Shanghai Bell insisted on returning this lot of products, since these defects would reduce the screw's endurance and, further, influence the exchange's quality. The manager of the local producer was astonished and did not understand this, as for this company, this batch of products was all up to their standards, and had certificates of inspection. Besides, the company had been producing screws for ages, and they had never ever come cross such a complaint.

Another example was that Shanghai Bell went to find a local producer for a component - a LED (light emitting diode). After having checked all technical features, the engineer from Shanghai Bell found, the angle of the light beam was not wide enough and asked the local producer to make a modification from 75 degree to 120 degree. He explained that, as the LED was used on the front panel of the exchange, a wider angle could make it more visible for operators. Although the engineers at the local company still believed that Shanghai Bell was pernickety, and the change was unnecessary, they eventually agreed to make the change. However, that was not the end of the story. After the angle was modified, another problem was found: the brightness of LEDs differed from one and another, which meant that, when they were fitted, on a same panel, some would look brighter and some dimmer. This again caused friction between two sides. The producer argued that this was too tiny an imperfection to be a problem, whereas Shanghai Bell side persisted with its standard.

Despite such problems, over time, local production of System 12 components has gradually materialised. This was not because government stepped up its intervention. Rather Shanghai Bell and local companies had become active players.

Since 1989, the production capacity of Shanghai Bell had been rapidly expanding and its demand for component was growing. Even existing local production of components, such as the production of racks and sub-racks and printed circuit boards in Shanghai Bell and the production of LSI chips in Shanghai Belling, could not keep up with the increasing demand. Increasing component imports would have increased problems of supply which had led to inconvenience and, sometime, had affected their ability to meet orders in time. Local component supply proved more reliable because transport problems were reduced as well as avoiding the need to deal with government officials to get import licenses. Cost reduction was another important factor, since local production was usually cheaper than imported products, because of lower labour costs and international transport costs. For example, in the case of cable import, the cost of air transport was higher than the cable itself. More importantly, the foreseeable future market of System 12 was clearly seen to be promising. For these variety of reasons, Shanghai Bell determined that it was the time to reallocate its component supply nearby.

During the same period of time, the macro economic environment pushed local manufacturing companies towards the market place. The state no longer took responsibility for selling whatever a state-owned company produced. Companies had to survive in the market oriented economy by themselves. They had to find new products and new markets, and to produce the products which could meet market requirements. In this circumstances, most local companies wanted to be a component supplier for Shanghai Bell. Even providing packing boxes for Shanghai Bell had made a box producer into a booming concern.

As both Shanghai Bell and local companies were all keen to produce components locally, things became much easier. Lacking finance, they went together to lobby the government, as well as mustering founds from their own channels. Even for quality problems their attitudes were no longer mutually hostile. Shanghai Bell provided local producers with as much help as they needed, such as approved technical documents with detailed specifications for each component, and helped solve technical problems in local production. At the same time, to let component producers understand the importance of product quality, Shanghai Bell invited local producers to visit the

Shanghai Bell's production workshop, to see how their components were fitted into the system through the assembly line and were functioning in the switching system. To ensure the local production quality in a longer term, Shanghai Bell established a programme with each local component producer for periodically inspecting the production process and examining products as well as random checks. This programme sought to track down the source of quality problems and finally helped local producer to solve them. To take the example of a local producer providing Shanghai Bell resistors. Every technical feature of the resistor was tested and matched the required specifications except for the hardness of the material for its two pins. That was a slightly too soft. For the local producer, it seemed merely a tiny technical differentiation. However, after visiting the production line in Shanghai Bell and seeing that, while going through an automatic inserter, many pins of the resistors were bent before being properly inserted into the printed circuit board, they realised that they were wrong.

By the time of my fieldwork in February 1993, government direct intervention for import substitution had gradually reduced, although its control on import licences and tariffs was still there. However, Shanghai Bell had established a supply network., which had been expanded to about 50 local companies. All locally produced components had obtained BTM's approval. Each component had more than one supplier, (e.g. the hybrid circuit had three suppliers). Because of competition between them, the price was also kept down.

During the course of domesticating production of System 12 components, local companies' awareness of product quality had gradually developed, production capabilities had been strengthened, although quality problems were still occurring from time to time, as these could not just disappear overnight. Even the most successful import substitution project - the Shanghai Belling joint venture project, to manufacture large scale integrated chips (LSI) for System 12 still had a reject rate of end products of 60%, lagging behind the producers in industrialised countries. But, compared to the reject rate at as high as 98% at the early production stage, it still represented big progress.

5.6 Summary and Conclusions

In the initiation of System 12 technology transfer, the Chinese government played the sole role in searching for available technologies across the world, selecting the appropriate switching system, and negotiating the transaction. The government was determined to bring China's telecommunications to the world level and, eventually, to build up indigenous technological capabilities based on its three step strategy of technology development. This was clearly reflected by its persistence in transferring all aspects of PDSS technology including the LSI chip production technology, which would not only suit China's telecommunications network, but would also bring the opportunity for China to gain access to the most advanced technology and ensure that China was able to produce the entire technology system independently in the near future. As a result of its efforts, the technology transfer agreement more or less laid the foundation for the co-operation between the Chinese and Belgian sides and so ensured the future success of the project.

All these government actions were crucial during the early stage of economic reforms for several reasons. First, after having been isolated from the world businesses for so many years, individual Chinese companies lacked experience to deal with international trade. Because the significant differences in political, social and economic systems between China and Belgium were very likely to pose considerable obstacles for companies on both sides, Chinese government involvement meant that the PDSS collaboration was a matter to be dealt with at the country to country level. Second, since a large-scale technology transfer project like public digital switching system required a large investment, there were very few companies in the world, that could handle the finance without any state help. Third, the collaboration engaged the Belgian government in the successful lobbying of COCOM to lift the ban on transferring LSI production technology to China.

Again it was direct and indirect government support that overcame acute problems arising in the course of implementing System 12 technology transfer. First of all, since in China the social and economic transition had only just started and this was still a centrally controlled system, government direct involvement was needed to handle the new establishment of a joint production venture like Shanghai Bell, which had to go through bureaucratic procedures at various layers in order to get official approval and to deal with difficulties - from land, human and material resources to utility supply - that were still allocated on a planned rather than market basis. Government approval was needed in particular at that time for Shanghai Bell to be allowed to adopt Western methods of management and to free it from the normal economic and political obligations (e.g. about taking on staff, involving political organisations in the management). MPT's support in gathering capable human resources across the country, and Shanghai local government's approval for this, greatly assisted Shanghai Bell in quickly mastering a wide range of technologies (needed for example to overcome technical problems occurring in the first installation of System 12 in the Chinese environment). The large MPT subsidy ensured the market for Shanghai Bell and extracted it out of the crisis at a critical early stage.

Having such a favourable environment, Shanghai Bell was gradually able to adapt System 12 to the poor conditions of the Chinese telecommunications network, and to modify some parts of the production process. Most important was high productivity which Shanghai Bell achieved through its efforts in building up technological capabilities in management, marketing, and resource allocation. In China's changing environment from a centrally planned system to a more market oriented one, Shanghai Bell learned to take advantages of its position as a newly established joint venture. It developed pragmatic policies and measures, and articulated its domestic and overseas strengths drawning upon its natural connection with the both.

Despite the significant success of Shanghai Bell in developing production capacity and in application software technologies, its technological capabilities in the innovation of System 12 and core production technologies, especially hardware technologies, were still very limited for several reasons. First of all, as a consequence of this model of technology transfer, the technology of designing and updating the core technology of System 12 was difficult for Shanghai Bell as a manufacturing company to master, especially as only limited technological support was available from within the country. Shanghai Bell has also limited opportunities for exporting System 12 exchanges, as this would offend BTM. However, it may be debatable whether it is necessary for Shanghai Bell to be able to independently innovate the core technology of System 12.

Apart from this, many hardware technologies, for example, production technologies in China were very poor (a general feature of the old socialist system), and would take quite a while to improve from scratch in terms of design of production processes and production quality control in particular. The best example was the production quality control. Its improvement had to start by improving people's perception of what quality means. Some problems, e.g. the inconvenience of using English as a human and machine interface language, were not economical to solve.

In terms of the production domestication of System 12 components, we can see that government intervention was not that successful until the domestication of supply became in the interest of Shanghai Bell and local industries, as a result of changes in the macro environment in China's transition. This issue showed clearly the different interests between the state and individual companies in building up technological capabilities. It also demonstrated the important role of both the state intervention and market forces in providing incentives for technological development.

Chapter 6:

The Case of Chinese Public Switching System

6.1 Introduction

This chapter presents the outcomes of my investigation of the Chinese HJD-04 case. It describes the process of development of HJD-04 technology. It then explores the state-owned firm, LTEF, which was one of the major developers of the Chinese system, including the situation particularly in relation to the development of production capabilities for HJD-04 and technological learning. Finally it analyses how the main technical features of this system were shaped by both social and technical elements involved in the development process.

This chapter consists of six sections. Section 6.2 depicts the entire process of the Chinese PDSS technology project: how this HJD-04 project was initiated and further progressed; what were the social and technical driving forces behind it; and how the social and technical elements necessary for this PDSS development were brought together and contributed to this development process. Section 6.3 and 6.4 shed particular light on the development of technological capabilities at firm level, focusing on the state-owned firm, LTEF, manufacturing the Chinese PDSS. The former explores the enormous challenges facing LTEF to survive in China's changing social and economic context. The latter focuses on how technological learning took place in the firm as well as the problems that remained, relating to the accumulation of technological capabilities and basic operational capabilities (e.g. production, marketing, management, etc.) in particular. They were essential to turn a blue-printed technology into a concrete product and to make profit out of it, especially since firm-level capabilities were very weak in China because of the previous socialist tradition.

Section 6.5 focuses on the local shaping of the artefacts. It shows how Chinese PDSS technology benefited from cheap electronic components available in the international market and knowledge of advanced foreign PDSS technologies being imported into China. It examines some special technical features of the system which reflects the make-up of the R&D team and their desires, linked to the broad social and economic environment at that time and knowledge about the PDSS and relevant technologies available domestically and internationally.

Section 6.6 summarises the main findings and concluding points in this chapter, and picks up some issues to be further analysed in analytical chapters.

6.2 The Process of Developing the Chinese HJD-04 System

The Chinese HJD-04 system was born out of the socio-economic transition taking place in China. Its development process reveals interesting elements of technological development different from the System 12 case. To make it easier to tell this story, I start by section 6.2.1 describing the three major actors involved in the development process. The entire process of the Chinese PDSS technology development is divided into two phases, illustrated in separate sub-sections. This distinction partly reflects my understanding of the development process and partly the nature of the process. Section 6.2.2 describes the initiation phase - how a military research team became the initiator of this project and how other social and technical elements necessary for creating this technology were built up. In this phase, although there were some uncertainties and reversals, an effective team was formed, and three major players worked together to overcome the technical, financial and political difficulties encountered, and obtained the technical success and official approval. Section 6.2.3 examines how, in bringing the technology to the market, tensions and conflicts emerged between these three parties around competition for profits and the large potential market. However the players still stuck together as they needed each other for further technological development.

6.2.1 Three Major Developers

Three institutions became core actors in developing the HJD-04 system - the Centre for Information Technology (CIT) in Zhengzhou Institute of Information Engineering of People's Liberation Army, the military research team, that was the initiator; the Posts and Telecommunications Industrial Corporation (PTIC), the industrial unit of the Ministry of Posts and Telecommunications (MPT) (see **Figure 1.**); and the Luoyang Telephone Equipment Factory (LTEF) of MPT, originally a cross-bar switch producer and later the main manufacturer of HJD-04.

CIT's involvement could be traced back to the early 1980s. In the past, this institute worked on designing large capacity computers, but only for R&D projects on national defence. Once economic growth became a main target of the country, the state budget for national defence, including military R&D projects, decreased. At the same time, the Military Commission of the Central Committee of the Communist Party issued an instruction calling for the army to make a contribution to the civil sectors. Under this pressure, the military research team of CIT started looking for some R&D projects in civil sectors.

Professor Wu Jiangxing played a key role in this episode. He was formerly senior engineer and later the head of CIT. In the early 1980s, Professor Wu was working in Fuzhou,[1] as a research fellow doing computer design. This was the time and the place that the first foreign PDSS, the Japanese F-150 system,[2] was imported and installed. The Chinese encountered many problems with this system: from the day the contract was signed, it took two years to get the system into operation. This frustrating experience highlighted the dangers for China from lacking its own technology and deeply impressed Professor Wu. Thereafter, he established a research team in CIT, which started working in the field of telecommunications.

The Luoyang Telephone Equipment Factory (LTEF) was one of four HJD-04 manufacturing firms under the MPT. It was also the earliest party to co-operate with the military CIT research team. LTEF was established in the 1970s to produce cross-bar telephone exchanges. One of 28 MPT firms, LTEF is a relatively newly-equipped company. It initially benefited from being state-owned. Soon after economic reform began, however, its products became less favoured by users as foreign advanced PDSSs began to pour into the Chinese market. Following the "foreign technology fever" (section 4.3), LTEF first bid for the joint venture with the Belgium Bell Telephone Manufacturing Company (which eventually became Shanghai Bell) and, later, was involved in another bid organised by MPT, for one of ten joint ventures to produce private digital switches. Having failed twice, in 1986, LTEF decided to co-

[1] Fuzhou is the capital of Fujian province on the Southeast coast of China.

[2] In Dec. 1980 the contract for import system F-150 between Fujitsu and the Post and Telecommunications Administration of Fujian province was formally signed. It was eventually put into operation in Nov. 1982. (Gu, ed. 1992)

operate with the military CIT's research team to seek for a new technological opportunity.

PTIC was the industrial unit of MPT set up at the start of the economic reforms to co-ordinate the activities of the MPT's 28 firms. It had previously undertaken the equipment provision for MPT's public network. As noted already in chapter 4, MPT was one of a few ministries, which was quasi-militarised historically. As a result, it had a very firm monopoly position in the country. However, economic reform had not left MPT untouched. PTIC, and MPT's R&D institutions, were allowed to become increasingly independent of MPT control. Under MPT, there were 31 R&D institutes. In the past, any technologies developed from these institutes were given freely to manufacturing firms. The reforms changed this relationship, because technologies were now perceived as profitable goods valuable in the market. Without an R&D base of its own, PTIC feared the loss of its technological resources. The pressure to save its loss-making state-owned firms also concerned PTIC. As a result, PTIC took a risk, and joined in CIT's technology projects.

6.2.2 The Initiation and Creation of Chinese PDSS

In the early 1980s, under pressure to turn to civil projects, Professor Wu studied available written materials on foreign PDSS technologies being imported to China - System-12, F-150 and E-10b.[3] PDSS is based on a range of computer technologies, completely different from the old generation of electro-magnetic switching systems. For people steeped in the telecommunications field, PDSS was not easy to master. But having experience in the field of computer technology, Professor Wu could readily understand it as simply another kind of computer system. This made him decide to attempt some work on digital programme-controlled switching systems.

The major task for the CIT research team was to find a partner with expertise in telecommunications, especially in telephone exchanges. LTEF as a telephone exchange producer was immediately under consideration. It was also a good choice that, geographically, LTEF was near - just over one hundred kilometres away from

[3] A French switching system, also the first commercial digital local exchange system of Alcatel-Thomson.

CIT, and politically, as the two cities which LTEF and CIT were located are in the same province. However, at that time, LTEF was concentrating on bidding for joint ventures, and had no interest in the joint development project. So CIT enlisted another telephone equipment manufacturer in the city of Changchun, in Northeast China.

In September 1984, CIT and its partner embarked on the project of a digital program-controlled private automatic branch exchanges (PABX). CIT chose this as a way of getting into switching technology, but one that was smaller scale and simpler than a public telephone exchange (for example, it only needed to interface with a narrow range of equipment, and regulatory requirements were less demanding). The technology was thus not a big problem for Professor Wu and his team. However, a setback occurred as the work was near completion. CIT's partner was informed that the Directorate-General of Telecommunications (the top telecommunications administration unit of the country, see **Figure 1.**) suspected that the proposed PABX was inadequate. It thus withdrew from the project, and the military research team was left alone to carry on. In June 1986, laboratory work was completed. The technical design of this PABX passed an examination organised by the provincial science and technology committee which concluded that the CIT research team had produced some "novel ideas" in design. This result exceeded CIT's expectations and encouraged the research team to continue their R&D in this area.

In October 1986, after LTEF's attempts to establish a joint venture had failed, it expressed an interest in CIT's project and received a positive response. In November the two new partners signed a contract to improve the design, and convert the laboratory prototype for production. Engineers in LTEF had expertise in telephone exchange technology, the requirements of telephone networks and the regulation of the telecommunication administration. The researchers in the military team were skilled in computer design. So the co-operation was quite successful. An improved PABX was delivered from the laboratory in August 1987 and, in May 1988, it entered into production.

At that time, as already noted, PTIC was also under pressure. After LTEF joined the R&D project, PTIC kept an eye on it, from time to time sending specialists to examine the product on the spot and to check the progress. Expectations arose in PTIC about the possibility using CIT to develop a domestic digital program-controlled switching system. Soon after, PTIC decided to invest three million Chinese yuan to develop a PABX with 2,000 lines. This project was only the start of a bigger plan, of which the second step was to develop a terminal (local) PDSS with 6,000 lines; the final target was a full-size PDSS.[4] Its investment in the military research team was, however, still risky for PTIC for both political and technological reasons: first, being outside the telecommunications sector, CIT was out of PTIC's control; and second, the stakes were large while CIT's technological capability was unsure. Nevertheless, PTIC saw CIT as a potential R&D base that could provide it the opportunity to fulfil its ambition. After the research team had gained enough practice on PDSS technology, PTIC planned to send the team to Singapore to develop a Chinese PDSS, with more advanced equipment and assistance of some experts from Taiwan and Singapore.[5]

In 1987, a contract to develop a PABX with 2,000 lines was signed between CIT and PTIC. Since then PTIC had played the role of general project manager and financial sponsor; CIT was the main technological force, with LTEF as a technical assistant as well as a test workshop.

PTIC's support was crucial to the CIT research team. The earliest result, a PABX of 1000 line capacity named HJD-03, was registered officially with the MPT. This was the largest capacity of digital programme-controlled exchange developed domestically at that time. The very success of HJD-03 and financial backing from PTIC greatly encouraged the CIT team. However, as a research organisation, largely driven by the motivation of technological novelty, it no longer had enthusiasm for developing another PABX (as PTIC planned). Instead, CIT aimed directly at a terminal (local)

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[4] By that time, digital computer programme controlled exchanges developed by CIT were small-size PABX and terminal (local) exchanges. The full-size PDSS meant that the new system shall have a capacity of approximately 30,000 subscriber lines and can be used as local or tandem (toll) switches.

[5] This is according to my interview with Professor Wu, Director of CIT, in Zhengzhou, 26 April 1993.

PDSS, which it saw as a necessary step to gain a full range of knowledge of PDSS technology.

PTIC's response to CIT's proposal was lukewarm, for two reasons: first, it was suspicious of the capability of the military research team; and second, it feared that the project would offend MPT which, as mentioned above, had been investing for some time in the development of another PDSS, the DS series.[6] Duplicated R&D effort was always considered a waste of money; in addition, PTIC might be suspected of being unfaithful to MPT by attempting to build up its own technological strength. PTIC did not oppose the programme; it just took a watching stance, thus *de facto* allowing the CIT research team to carry on anyway.

Eventually, as the military research team had hoped, a workable terminal (local) PDSS, HJD-15, was developed. From the viewpoint of CIT computer specialists, their major technical obstacle - the lack of expertise in telephone switching systems - had been removed. In November 1989, PTIC agreed to the CIT's proposal to develop a full-size PDSS. It organised a conference to examine the development plan and the feasibility of the Chinese PDSS, to which it invited almost all authoritative experts in Beijing. The result was ambiguous. Although the telephone switching experts were not able to understand the detailed design (because of having less experience in computer technology), most of them found the architecture of the system distinctive. Nobody could be sure that the project would be successful in the end, but the conference concluded that "if the design can be proved in practice then it will be a big success". Consequently, the development project was initiated. This involved registration of the project with MPT. The system was registered by the PTIC with the name HJD-04, although officially, HJD was the name for a range of PABX technologies. By using this name, PTIC could avoid being accused of duplicating research or offending MPT. In fact, the development still irritated MPT - but, so long as PTIC did not submit its application for approval, MPT could not respond to it.

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[6] The system DS series were a range of Chinese PDSS technologies. DS-2000 was the first successful PDSS developed by Chinese R&D teams and latest version was DS-30 (see also section 4.3).

The HJD-04 development project went smoothly, until test-system debugging was initiated in October 1990. Hardware debugging was completed, but serious problems arose on the software side. According to the original, rather optimistic plan, this test-system was to be put into test operation by the end of 1990, and simultaneously MPT would conduct a general examination. When the time came, MPT insisted on carrying out the examination on schedule, while the project was facing serious problems on software side. This put the joint R&D group under enormous pressure to show that the product could succeed.

At that stage, MPT was not happy to accept the project, probably because the work was done by a military research team from outside the sector and, to their even greater irritation, because PTIC had become involved in the project without its approval. Besides, the system had been declared by its developers to be better than the system DS series which was developed by MPT's own research institutes.

Eventually, PTIC managed to get the examination postponed, but MPT set some other obstacles. It did not carry out the examination, but instead demanded documentary evidence that the initiation of the project was approved by the authorities in MPT. Because the HJD-04 had not got MPT's approval as a *bona fide* PDSS project, in December 1991, a presentation of the project proposal was held in Beijing, before the formal examination of the system. Eventually, MPT sent a 20-person inspection party (a daunting prospect since the HJD-04 research team was only 18 people) to carry out an initial examination of the machine. Among the examiners were some who had been involved in the development of DS-2000 and DS-30, and experienced engineers from Shanghai Bell. The final inspection party was even larger. Indeed, it was the most authoritative examining party ever sent by MPT, and included examiners from many relevant ministries and organisations. The final result was favourable, and the HJD-04 was, at last, officially acknowledged.

6.2.3 Further Development - Bringing the Technology to the Market

From then on, HJD-04 development entered another phase related to production and to markets. No longer a bastard child, the technology was sought after by many companies who saw its potential market to be immense. The three parties co-operating in the HJD-04 project began to face problems, such as product quality, further technology improvement, and resource allocation. New conflicts emerged among them with respect to each party's right to possess the technology and each party's responsibility for the group's co-operative actions.

According to the contract, PTIC possessed the right to produce HJD-04, while CIT held intellectual property rights for the core technology - for which it received a certain percentage of the profit from the producers, and took responsibility for training engineers and technicians from factories to master the technology. PTIC allowed four of its manufacturing firms (including LTEF) to produce the HJD-04 system. LTEF had no special role or relationship once the other three firms had joined in as producers.

In China, economic legislation was new - for legislators, implementors and undertakers alike. The relevant legal system and provisions had not been completed and elaborated. In the past, if conflicts occurred between people or organisations, they went to the Party for justice. Now, with only a hazy understanding of the law, people were having to use legislation to protect their rights. At the same time, many businesses and organisations ignored the laws; some even took advantage of imperfections in the legal system, and people's immature understanding of it, to avoid the constraints of the laws upon their efforts to pursue profits.

In the HJD-04 case, the technological co-operation surrounding its development was not actually based upon the contract between the CIT and the PTIC. Instead, it was largely based on mutual understanding of the importance of the roles of each party. This facilitated co-operation in the initial development of HJD-04. However as it moved towards commercial exploitation, efforts to maintain or enhance each party's strength in this co-operation led to a series of conflicts.

One conflict arose because CIT sold its technology to other manufacturing companies without PTIC's permission. The telephone switching market was so attractive that many companies wanted to obtain the HJD-04 technology - for instance, professional telephone equipment producers or newly-established electronic joint production ventures belonging to the Ministry of Machine Building and Electronics Industry

(MMEI),[7] as well as some military factories. CIT's action increased the number of HJD-04 manufacturers to seven or eight. This greatly offended PTIC, which considered CIT's move an illegal action and a breach of the written contract. But PTIC dared not risk damaging its relationship with CIT, as their co-operation was obviously crucial for any further innovation of the technology.

So PTIC fought back, but without a head-on battle with CIT. MPT's monopoly in the management of the telecommunications sector was still unshaken, up to this point. Its administrative unit in telecommunications, the Directorate-General of Telecommunications, was in charge of the whole public telecommunication network and all telecommunications services. Each new type of switching system had to be approved by the Directorate-General of Telecommunications before being used in the public telecommunication network. However, at that stage the HJD-04 system had not obtained the necessary licence for installation on the network. In this situation, PTIC's strategy was to stop HJD-04 units produced by non-MPT companies from gaining access to the public network. Instead of applying for a full licence for the HJD-04 system to enter the public network, it managed to get Directorate-General of Telecommunications' permission with the proviso that the system was allowed to be installed in the network for the purpose of "test operations". This permission was exclusive for PTIC's companies. With this, *de facto*, PTIC's companies could produce and sell their products as much as PTIC wanted, whereas the other HJD-04 producers could not!

The attitudes of the ministries and top state leaders involved were interesting. The above dispute inflamed the already sore relationships between MPT and MMEI. Each stood by its own companies. MPT took the HJD-04 technology as its own and tried to protect the right of PTIC, while the MMEI accused MPT of exploiting its unfair monopoly over the PDSS market. PTIC was worried that MMEI could take revenge, through its control of the tariff rate on imported components needed for the production of HJD-04. The case was passed on to some senior leaders. One state

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[7] The MPT was originally established as a posts and telecommunications administration entity for the country. The MMEI was an industrial management body. However under Mao's self-reliance philosophy, the MPT and MMEI both established their own industrial enterprises during the Cultural Revolution. As they both have their own telephone switch producers, this gave rise to confrontations between them.

councillor, who had once supported the HJD-04 project when it was in difficulties, expressed his personal opinion that "as long as the HJD-04 is an indigenous Chinese technology, why not stand for the whole nation to develop the technology all together first and leave conflicts to later on".[8] So, the dispute on the surface was calmed down. But, a major initiative aimed at establishing an alternative telecommunications network had been brewing within MMEI and several other ministries, in order to break MPT's monopoly in telecommunications services.[9]

The relationship between PTIC and LTEF was also complicated. On the one hand, PTIC had been doing its best to help LTEF in finance and marketing; on the other, it had been trying to tighten its control over LTEF in order to make more profit from it. In turn, the firm enjoyed PTIC's support, while trying to avoid its tight control.

PTIC pursued its interests in several ways. First, it successfully lobbied the government, with the result that the HJD-04 technological development project was put under a state scheme in 1992. A $4.98 million long-term loan with low interest[10] was offered by the state for the modernisation of the production assembly line in LTEF's workshop. With this sum of money, plus $300,000 which it generated itself, LTEF could purchase advanced machines and facilities needed both from abroad and within the country.

Second, PTIC persuaded the government to waive import tariffs specifically for the HJD-04 components with effect from late 1993.[11] This was critical, since the system used many imported components, the tariff on which might be as high as 140%. Third, PTIC established a new company, Beijing Long Term Technology

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[8] This is according to my interview with an high ranking official in Ministry of Machine Building and Electronics Industry (now, Ministry of Electronics Industry).

[9] Apart from the public telecommunications network, in China, there were several private networks run individually by the Ministry of Railways, the People's Liberation Army, the Ministry of Electronics Industry, and etc. which have excess capacity. In early 1993, they were to initiate a joint company - Lian Tong Corp. and to jointly establish a rival network, in order to challenge the MPT. This plan was still being debated when I was there in April 1993.

[10] This is according to my interview with the official who was in charge with the HJD-04 technology. However, when people in the LTEF mentioned the sum of money, they simply called it "the money given by the state". For state-owned companies, a long-term loan is equivalent to a gift, because the firm does not belong to anybody, neither director nor the others in the firm. In the case of a 20 year term, these directors and managers will probably have left by the time of repayment. Whether this will make trouble to their successors is not their concern.

[11] This is according to my interview with a key official in PTIC, 6.4.1993.

Corporation, to deal with all business and matters concerning HJD-04 technology - purchasing equipment, importing components, capital investment, technology control, and so on. As an independent company (which in fact had very close relation with PTIC, as shown by the fact that its director was the head of PTIC's Directorial Office), Beijing Long Term Technology Corporation could freely partake in commercial activities. Since LTEF was not allowed to gain access to foreign business partners directly, the purchase of components and machinery must be carried out through other commercial companies. This was a highly profitable business. Soon after its establishment, Beijing Long Term Technology Corporation replaced the trade companies who had been undertaking LTEF's business, importing components and purchasing machinery from abroad. However, because of Beijing Long Term Technology Corporation's lack of business experience, problems in supply arose which cost the LTEF a lot.

Finally, as part of the reforms to bring in a market system, marketing became an undertaking of firms, rather than of the PTIC. This weakened PTIC's total control over the production volume of firms, which was directly associated with its drawing profits from its daughter firms.[12] However, PTIC found an alternative way of exerting control over its firms. It kept secret from the firms the password necessary to process all the software for producing HJD-04 systems. Thus, when LTEF got orders from users, it must apply for decoded software from PTIC's new company, Beijing Long Term Technology Corporation, and pay it for production of each line of the system. In addition, to gain more technical control over its partners and daughter companies, PTIC established a HJD-04 software centre.

LTEF was unhappy with this PTIC control but, as a daughter company, it would not fight back. In any case, it relied on PTIC for finance, as well as for obtaining government support. LTEF had learnt the danger of lacking technology of its own, and was determined to strengthen its technological position. In February 1993, the firm established a research institute in which it assembled its best manpower. Ambitiously, the firm hoped that one day it would be able to master the entire

[12] The PTIC as an entity which functioned as an administration organisation also lacked money, under China's economic phenomenon that every body and every work unit was trying to make profits.

technology of HJD-04 and to extricate itself from external technological dependence.[13]

LTEF had worked closely with CIT's research team during the technology creation stage. However, after the technology was developed for the market and became profitable, technological capability became an important card to play in the power balance among the three parties. Information flow between users, manufacturers and the R&D institution was crucial in this technological improvement stage. But LTEF and CIT were no longer exchanging their expertise freely, because both parties were trying to protect their technological position. For example, a problem had been occurring in the firm since the beginning of production, because a component with two pins which had a larger diameter than the holes they were to fit in on the PC board. Before soldering, the two pins had to be filed smaller to fit the holes.[14] It only needed a very minor change in the design specifications of the board to overcome this problem, but this had not been done by the time of the study (April 1993). The LTEF said that the change should been made by CIT, since the firm was not allowed to change any documented specifications. However, CIT argued that LTEF should be responsible for this matter. On another occasion, CIT asked LTEF to get regular feedback from users, with whom LTEF had close links, but LTEF did not respond. So, CIT had to send its own team members to the field to collect feedback.

The same type of technology protection activities occurred among HJD-04 producers under the MPT. They were competing with each other in almost all aspects, including resource allocation, marketing and technological capability. The desire to prevent technology leakage between these four firms ruled out information exchange and co-operation which could have promoted overall technological development.

Confrontation (both overt and covert) had been a recurring theme in this stage of the improvement of HJD-04 technology. In spite of these conflicts, however, all parties

[13] On one occasion, some people in the firm talked about breaking the security code of the software of the HJD-04, but the head of the firm immediately received an angry response from the PTIC, indicating that it would definitely not be allowed. In contrast, Professor Wu did not take the idea very seriously. He laughed and said to me in the interview that it would probably have been impossible anyway.

[14] This impairs the quality of soldering, because the coating material of the pins is designed for making a good soldered joint.

involved in the project know that they were bound up with each other through the HJD-04 system. They all knew that they had to put these conflicts behind them. According to current plans, CIT was to complete a new version, HJD-04AD (advanced version) in 1994, with new functions (for example, using No.7 signalling system and remote modules). In a few years, ISDN and intelligent networks would be available. The question was how to conduct a co-operative relationship at an appropriate level of competition. In order to achieve this, in 1993, PTIC established a new co-ordination organisation named 'Production Co-ordination Committee', with the aim of finding the best solution to conflicts between institutions, and of encouraging co-operation to accelerate improvement of the technology. They knew very well how important PTIC and CIT were for it - with respect to financial, political and technological support - in the past, currently and in future.

6.3 LTEF - Technological Capabilities at Firm-Level

Technological capabilities at firm-level are ultimately critical. The blue-printed HJD-04 technology had to be turned into products and thereafter to be tested in the market. This section illustrates how LTEF performed and contributed to this technological development process. It explores the problems and difficulties which had surrounded this state-owned firm since the economic reform.

Sections 6.3.1 explores how LTEF developed its production capabilities in the struggle to survive during the transition, and spells out the organisational reform of the firm to root out the inefficiencies and lack of incentives stemming from the old system. Section 6.3.2 examines how technological learning took place under intense pressures to overcome obstacles arising from both the traditional economic system and the transition. This section provides a detailed insight into how the firm operated and the problems it faced during the economic transition period, as these are typical to a state-owned firm in China.

6.3.1 Pressures and Opportunities in the Transition

Luoyang Telephone Equipment Factory is a fairly typical state-owned enterprise, in terms of the institutional structure, incentives and operating mechanism. The project to build the new factory from scratch started in 1972 under the "self-reliance" policy of the government, prior to economic reform, that the country must build up the telecommunications industry on its own. The factory came into operation in 1980, producing cross-bar public telephone switches with a maximum capacity of 200,000 lines per year. This domestically designed switch was an advanced technology at that time in China and the technology was freely transferred from an R&D institute under the state scheme.

Like many state-owned factories that were located away from the coastal area during the "cold war" in order to avoid the imperialists' attacks, LTEF was situated in the middle of China. The factory lies in the remote outskirts of the city of Luoyang, in Henan province. This created inconvenience in transport between the city and the factory. Because of this, when the factory was set up, it decided to establish its own social welfare facilities for its employees working in the factory: providing houses near by; kindergarten and schools for their children; a hospital, a post office, telecommunications service; buses to and from the city to the factory seven or eight times per day; restaurants and canteens, guest houses, bathhouse, travel agent and all kind of services. As staff described vividly: "Here we have everything except for a crematorium".

The factory employed a large number of staff which was due partly to labour-intensive production, and partly to the socialist ideology that was supposed to provide everyone with a job. By 1992, the number of employees was over 2,700. The whole community including the families of its staff was estimated as around 7,000. People's jobs were permanent. The director of the firm played a role as head of a community, and accordingly managers of each department and section took care of their staff to a large extent. For instance, if someone was ill, the company would be obliged to send him/her to hospital and pay the expenses. If someone's family experienced disaster, his/her boss should, on behalf of the group, offer help and express their sympathy. Similarly, if a member of staff could not find a partner, the trade union of the factory would possibly play the role as a match maker.

As already noted earlier, the LTEF was a newly equipped cross-bar switch producer. It used to produce almost every component for the cross-bar switch, and the process was conducted completely within the factory from the input with raw materials to the output of the finished switch. All raw materials were supplied, and products were sold, at fixed prices by arrangement of the state. All the chief officials regarded as important to the firm, such as the director, major department managers, chief engineer and accountant etc. were appointed by the MPT. The recruitment of graduates the factory received every year from universities and technical schools (most of which were run by the MPT), was organised according to the state plan. Without the economic reform, a factory like the LTEF would be a plan-taker immune to any problems from the imbalance between input and output.

Soon after LTEF established its production and social facilities, its social and economic environment, and the underlying socialist doctrine begun to change. In the first five years of the economic reform, it remained untouched within MPT's protection. But it sensed the insecurity of its position due to one event. In the beginning of the 1980s, MPT offered the newly equipped LTEF factory to its foreign partner BTM[15] to establish a joint production venture. The offer was turned down and the foreign partner chose another cross-bar manufacturer in Shanghai as its base. This made the LTEF feel sour. However, at that time, the economic reform was merely a gentle breeze for the firm, and it did not exert much pressure.

In 1984, the central focus of economic reform had gradually shifted to the reorganisation of the industrial sector, involving provision of greater autonomy to firms and reduction of government protection. In other words, firms had to organise fully or partly their resources and sell their products in markets.

This made LTEF face both internal and the external pressures. Financial constraints became stringent - how to sustain the unduly large work force and more urgently to feed about 3,000 staff. The existing institutional establishment - once well suited for the central planning system - did not provide the structure and incentives for high productivity. Instead, previous socialist advantages - the significant community

[15] It was Bell Telephone Manufacturing Company of ITT, now it belongs to Alcatel.

function of the firm - became a heavy burden. The emergence of the PDSS market favoured foreign advanced systems rather than Chinese cross-bar technology even though international prices and import tariffs made them more expensive. At that time, some authorities suggested that cross-bar could remain for quite a while in China. As noted in chapter 4, however, orders for cross-bar products decreased sharply.

The LTEF was faced with two alternatives: either to co-operate with CIT in seeking for a new technological opportunity or to bid for joint venture projects. It turned down the earlier offer of CIT because of the lack of enough momentum at that stage. After it failed twice in its bids for joint ventures, it could not afford to not join CIT. For LTEF, it was an chance to renew its technology and ultimately to maintain its position in the market.

In collaboration with CIT, LTEF provided expertise in exchanges and networks in the telecommunications field; it offered its workshop as a test ground and undertook the designing of a variety of racks for holding switches. In turn, it benefited from producing new technologies: the PABX HJD-03 which at that time was the digital switching system with the largest capacity developed in the country; and the terminal public digital switching system - HJD-15 which was also new for the country as a locally developed system. By producing these two systems, the firm turned around its loss-making position. Later, the firm obtained HJD-04 technology which had a great potential in the domestic PDSS market, although it had to compete with other HJD-04 producers inside and outside MPT's territory.

6.3.2 Reform to Survive

Efficient production capability was the key to turn the new technology from a blue-print to a product which could succeed in the market. The situation had reached a point where the firm could not move on without restructuring its entire organisation, to address productivity and the requirements for producing the new technology. However, this was the most thorny problem for a state-owned firm like LTEF. Restructuring would touch every member of staff and their individual vested interests.

The stakes were so high that the firm would have avoided getting involved in these issues if this had been at all possible.

Instructions for reform eventually came from above. These were applied all over the country, although the speed and incidence of their application varied from place to place. At this stage, the major target was an administrative innovation in firms to shake off the rigid system, popularly known as "smash the big iron rice bowl", it was based on a belief that employees of enterprises from shop-floor workers to the director of the firm lacked motivation to work hard. The new one to be built, described as the "responsibility system", was based on a contractual arrangement,[16] which also defines the respective roles of the enterprise director, Party secretary and the other chief managers. However, because the rules of the new arrangement, and the dogma of "socialist market mechanism" underlying it, were not explicit, people's understanding of the responsibility system varied considerably.

At LTEF, the most urgent problem was not the rigid administration system, but the unduly large work force especially since the new technology required much less labour. As it was a relatively new firm, and staff were newly enroled and young on average, people's performances were not that bad. However, the production of HJD-04 was capital-intensive, requiring only 800 to 900 people, whereas the total work force in the firm was 2,700. It therefore faced a dilemma: to follow 'socialist' principles the firm had to be concerned with the basic needs of the majority; to fit the 'market mechanism' it must cut off its community roles and be more efficient. How to solve this problem became critical for the firm, as well as, a matter of concern for the director who was in charge. As he noted

> The market economy is the market economy, no matter whether one calls it socialist or capitalist. What I care about is that I have been living with people here for so many years I can't see them jobless. If we just kick workers out after they have served this country for so many years, where is justice and humanity? We are trying to find a way for them to make a living. Otherwise we would rather wait for a solution from central government (The Director of LTEF, 22.4.1993).

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[16] This kind of contract varied from firm to firm. Usually, workers signed contracts with the head of their departments, heads of departments signed with the director of the firm and the director with his boss at higher level organisations, accordingly.

This was a common reaction in state-owned firms all over the country, especially from those who, like the director of LTEF, had lived together with staff in a same living quarters for many years. However, as the financial pressure on the firm intensified, some measures had to be taken.

LTEF eventually established an internal labour market. Surplus labour was allowed to stay at home on 70% of their salary. A bureau was set up to organise the internal labour market and meanwhile seek new jobs for them, e.g. to find some products which were in demand at the time for them to make; to arrange for them to work temporarily or long term in other companies which needed spare labour; to train them technically in order to return to workshops with different skills, and etc. This had the positive result that each department of LTEF could choose better labour from the internal labour market. The internal labour market did not solve the fundamental problem of the unduly large work force, but it created great scope for engineering a dynamic system. Its positive side was that it created a buffer that reduced the current intensity of immediate pressure on LTEF. As it was accepted by the majority of its people, it did not produce any danger of instability which was a major concern of the administrative group of the firm.

Simultaneously, the firm re-organised its management institutions and operating systems, and introduced new incentives. In preparation for this reform, the firm sent a large group to visit Shanghai Bell, in order to adopt foreign managerial methods which were considered effective. In the last quarter of 1992 when the internal reform was unfolded, LTEF adapted the "responsibility system" to introduce what it described as the "optimum constituting system". Under this new company constitution, posts became selective with appointments made on only a one-year contract; and the performance of an individual in his/her post was annually assessed. The role of each post was defined more clearly than ever before, especially that of the managers of each department. They had more scope to make decisions, and took on more responsibilities, compared to the previous tradition of collective decision-making. The biggest change was with the Department of Production. It became more autonomous and had its own internal accounting system which gave a great scope for the department to fully use its income as a means to motivate workers to improve both quantity and quality of production.

A new salary structure was introduced, described as "performance-oriented salary". Under this system, the salary was broken down into two parts: basic pay and performance-related pay. The basic pay depended upon how long the employee had worked in the company or in other state-owned organisations; what qualifications he/she had, etc. The performance-related pay was based on performance, in so far as the employee's working hours and output met the standards set by the firm, and the output exceeded the quota. Alternatively, good group and departmental performance would lead to bonuses in the individual's salary. The sum of these two parts is then weighted by a measure of the quality of individual's work.[17] In this way, control over workers was intensified through a set of detailed regulations and disciplines. In addition, because of the great size of the labour force, there were many to choose from for each post. Thus, for people with posts, the workers standing-by were a pressure on them - an "internal" reserve army of labour!

All these changes focused upon improving the productivity of the system. Material incentives were seen as an important means of motivating every cell of the system to achieve the firm's aims. At the same time, efficient production organisation was put on the firm's agenda (see below). This reform, more or less, achieved its purposes. Workers on the shop-floor were working harder than before. When the firm needed, they worked in their lunch breaks and in the evenings. So did the engineers, especially young and unmarried engineers. Since they live alone in the dormitory of the firm (just 5 minutes walk from the workshop), they often came back to work in evenings[18].

In spite of these achievements, the state-owned firm could not yet get rid of all its burdens. In comparison with private and joint venture companies, LTEF was still less productive. Because government tariff policy also favoured joint ventures[19], the

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[17] The formula for counting is "the total salary = (Basic salary + performance-oriented salary) x Quality as weighted variable from 0 - 1.

[18] This is according to my personal interview with three engineers and technicians. All of them had graduated from university and left their home town and came to work in this factory. One had got married living in the dormitory, the other two were single.

[19] For attracting foreign investment in Chinese industry, the government issued several tariff bills: "Regulations for the Implementation of the Law of the People's Republic of China on Joint Ventures Using Chinese and

disparity between a state-owned firm and a private and/or joint venture firm was big. As one department manager said:

> We are competing with these companies on an unequal basis. As such, we will never catch them up (Manager of the Planning Department, 23.4.1993).

Apart from these developments, the nature of the state-owned firm had not changed much to date. All of the social welfare facilities were still there; without them staff could not live. For instance, if the firm cancelled the bus, people living in town would have to walk for hours to get to the factory. The firm's role in taking care of staff well-being had not changed much either. According to the Director, recently, when a newly employed worker was seriously ill, the firm spent several tens of thousands of Chinese yuan on his medical expenses. As he explained:

> Tell me, how could I just kick him out even though we are very tight in finance? We are a socialist country after all! (Director of the LTEF, 4.22.1993)

When I was interviewing the manager of the Department of Production, somebody came in urging him to leave: he apologised to me that, as a head of the department, he must act on behalf of the whole department and go to visit a member of staff whose mother had just died. At that time (April 1993), the firm was laying pipes in its living quarters to install a central heating system to improve the staff's living conditions. The former head of the Directorial Office of the PTIC viewed this situation in a broader sense. He said:

> We state-owned enterprises were and are still undertaking the role as a backbone of this country. Now, the other companies can select people who are relatively young and healthy, and can escape from paying pensions, providing medical care or child care and the other expenditures. But it is us who are looking after possibly their parents, spouse and children. Everybody knows the ideal structure of a family is that father works for joint ventures and mother works for state companies, so their dependants can still be in the welfare scheme. Without us, this society would have already lost its balance (The former head of the Directorial Office of the PTIC 6.4.1993).

Foreign Investment", promulgated by the State Council on 20 September 1983, indicated that, '... A joint venture can apply for reduction or exemption of industrial and commercial consolidated tax for a certain period of time ...' (Shanghai Foreign Trade Committee, pp 223-256) ; "Some Provisions of the People's Republic of China Concerning the Reduction of or Exemption from Income Tax in the Absorption of Foreign Funds", 21 September, 1982, indicated that, '... A newly-established joint venture, jointly operated for a period of more than 10 years, with the approval of tax authorities upon an application filed by the enterprise, may be exempted from income tax in the first profit-making year, and allowed a 50 per cent reduction in the second and third years...'(Shanghai Foreign Trade Committee, pp. 386-391). Along with that, many coastal cities and districts added some more radical local policies to give joint ventures more privileges.

6.4 Technological Learning

Pressures stemming from the new economic environment compelled state-owned companies like LTEF to seek newly emerging technological opportunities, and to strengthen its basic capabilities as an enterprise to survive in the more market-oriented system. The future facing them provided little options: to involve intensively in technological learning; otherwise to drown slowly in the increasing competitive environment.

To a state-owned company like LTEF, the environment for technological learning was not the best, compared to private and joint venture companies. Learning processes were also not the most pleasant, as they had inherited substantial social burdens. However, LTEF was drawn into the learning process, and has gradually built up basic technological capabilities.

6.4.1 Resource Allocation in the Market-oriented System

State control over raw materials had been gradually liberalised. A state-owned firm, like the LTEF, was ultimately bound to lose its privileges of getting low-price supplies. However, the firm remained dependent on the state, and in particular on MPT, until it found that the state price was much higher than that in the freely negotiated market. This discovery provoked an important change of attitudes in LTEF. Its immediate reaction was that it sold its spare copper materials bought in at a low state-regulated price on the negotiated market at a much higher price without the state's permission. More importantly, through this the firm learned that it had to rely on itself.

To produce HJD-04 technology, a large number of components needed to be imported from overseas. But LTEF did not have direct access to overseas companies. Components had to be purchased through various means: usually through some domestic trading companies which then purchased the goods from trading companies in Hong Kong. And the companies in Hong Kong might have ordered the components through some other intermediaries. As a result, LTEF found it difficult to know who the real suppliers were; worse, the quality of components differed to a large extent, and the timing of the shipping-in of the goods was often off schedule. LTEF's frustrating experiences gradually taught its business team how to deal with these problems, e.g. to find alternative suppliers, to make more practical plans in provision and etc.

Despite its severe problem of surplus labour, LTEF was at the same time short of qualified technicians and engineers for the new technology production. The market economy had resulted in large disparities between private, joint venture companies and state-owned companies with the ability to provide increased rewards for such manpower, so that LTEF, which could not provide high wages and bonuses, lost its attractiveness as an employer.

In the past, people, once assigned to work in the firm, could only leave with the firm's permission, unless the transfer was ordered from a higher level. Now because political control upon private and joint venture companies had been loosened, they accepted new employees without official leaving certificates as long as they had professional qualifications. Skilled workers and qualified engineers could quit and leave the firm for a better paid job in a joint venture or private company locally, or even in the southern economic zones. LTEF had not experienced much of a problem with people leaving, because once people were settled - e.g. when their children were in school or kindergarten and their spouses were working in the same community - it was not easy for them to leave. However, there was an urgent need for the firm to recruit new manpower and then get them to stay.

One of the most reliable sources of new and skilled labour for LTEF had been the recruitment of new graduates, but even this became difficult. Under the centrally planned system, graduates from universities, and especially from those MPT universities, were annually assigned to MPT enterprises. The reforms which had made technology more important, for similar reasons, increased demand for university graduates. Graduates, in particular those with a good degree or from a reputable university, could chose where they preferred to work. As state-owned firm, the LTEF was clearly not a favoured choice, especially because of its geographical location. The manager of LTEF Personnel Department said of these difficulties:

> In the past, according to the state quota, graduates were assigned to our factory annually. They came but hadn't got enough to do. We often felt there were too many graduates and only a few suitable posts for them. Now, things have changed. My boss has been constantly pressing me to get some new graduates. It's not easy. We are not Shanghai Bell which has got privileges. Well, as long as we are determined to do it and are not stingy with money, we will make it. I have been travelling around attending 'human resource exchanging meetings'.[20] We are not attractive, indeed. We can't get the best students, but it doesn't matter. I always tell them the truth: our living conditions are not that good, but our HJD-04 is good, it's a Chinese system; the mastery of this technology is like having personal property [as the skills are in great demand]. We need those who are willing to work on the technology. We have got some contracts done this year [1993]. This year, our budget for this recruitment is about 100,000 yuan, with it we can get 40 graduates. You know, we have to pay for it. Well, it is understandable that universities need money too (The head of Personnel Department, 23.4.1993).

On the one hand, the firm was actively recruiting manpower from external resources. On the other, it was running a retraining programme - by sending people to study in universities, notably, to CIT to be trained directly in its laboratory; and by inviting experienced and knowledgeable engineers within the firm, and experts from the CIT, to give lectures in the classroom or teach practically in the field. As the director of LTEF understood:

> Now, we see that competition means a race in technology rather than only in the market. After all this is a competition for manpower (Director of the LTEF, 22.4.1993).

Also the firm had been trying its best to attract key staff to settle down in the community, by providing them with the best living and working conditions that the firm could afford. The new incentives were: higher salary, better housing and, moreover, job satisfaction.

6.4.2 Production Capability - to Achieve High Productivity

People in LTEF learned gradually that there is a profound difference between a centrally planned socialist system and a market mechanism. "Efficiency" and "high productivity" are essential for a market-oriented system, and are closely linked to the profitability of a firm. In the past, the socialist tradition was to a large extent designed to protect people from the competition that results in brutal class struggle. Under the

[20] This was organised for the purpose of letting companies and student get to know each other.

central planning, high productivity was hardly a major consideration. Now, two key factors affected the firm's manufacturing operation. The first was derived from the new technology. Cross-bar was based on electro-mechanical technologies, whereas digital switching like HJD-40 is based on electronics technology. Production of cross-bar switching technology was labour-intensive whereas the HJD-04 is technology-intensive. For the firm, it was a fundamental change not only in production technology, but also in production organisation. Hence, the second problem was how to effectively control production quality in this new situation.

In the previous production of cross-bar switches, LTEF used to produce almost every components by itself. However, the only part of this technology which could be used for the HJD-04 system is the technology of racks and rack units. The LTEF believed that its capability in rack design and production exceeded the other HJD-04 producers. The very new and difficult undertaking for the firm had been the assembly of printed circuit boards. In the beginning, assembly was done manually. Later the firm was equipped with a wave soldering machine and a pin bending machine. After the machine bent the pins of circuit components, they were inserted into printed circuit boards by hand and delivered to the soldering machine. Some joints were still soldered by hand. The final procedure of the production was testing the products, for which the workshop lacked proper apparatus.

The first and biggest problem was product quality. In the past, one of the socialist economic phenomenon was shortage of material supply. Because of this, products were allocated on a rationed bases. In practice quantity therefore came to be more important than quality. As a result, there was little perception of the need for quality. However, the new HJD-04 production was put in a competitive environment in which advanced foreign system had already set high quality standards for any switching system. Since LTEF lost the protection of the state and was pushed into the market, it had to compete with foreign companies, joint ventures as well as the other HJD-04 producers. From the market it learned the vital importance of quality.

"No quality, no quantity" became an almost everyday phrase spoken by people in the firm from the director to shop-floor workers; it was discussed on programmes made by the in-house wired-broadcaster everyday; and mentioned by every manager I interviewed. It was not a phrase from propaganda; rather, it was a lesson learned from their experiences in markets. Without quality, there would be no market, and the firm would not survive. That was the reality they were facing. Hence gaining high product quality had become the major task of the firm. More importantly, people's perception of quality with regard to market standards had gradually been changing.

Changing people's perception of quality was not enough. In the past, people also paid attention to product quality, but because the production was not the only undertaking of the firm, quality control was often left behind while the other tasks took precedence. Quality control was addressed by a series of disconnected mass movements like other political tasks. After each campaign, quality would remain high for sometime and then deteriorate until another movement was needed. From its recent experiences, the firm learned that quality control needed a set of well designed methods and that these methods needed to be implemented over the whole production process. In the beginning of 1993, after the institutional reform of the firm, the Department of Quality was set up and a knowledgeable person[21] was made head of the department. Compared to the previous quality control organisation which involved several small teams working in individual departments, the new department had more power.

The first target of the new department was to improve the quality of imported components. As mentioned above, the firm had no direct access to international markets, with the result that these components' quality was unpredictable. For this, the firm increased its investment on testing equipment within the factory. At the same time, some components were sent out of the province to two electronic R&D institutes which had appropriate test apparatus, as the firm lacked qualified labour and necessary equipment at that time.

The implementation of quality control methods in the process of production was more difficult, given the shortage of expertise, manpower and the means of production

[21] According to my interview, he had been involved in quality control work since 1973 and was sent to study on production management in some college during that time.

needed. For instance, in the workshop, many work procedures were done manually. Women workers sat in lines, soldering components on printed-circuit boards by hand. Under these conditions, the quality of production varied depending on individual workers, their experience, attitude towards their job and, possibly, upon the time of day and on how workers felt. In addition, uneven availability of components often made the things worse. When one lot of imported components was rejected by the LTEF due to poor quality and needed to be returned to the supplier, the time delay was severe. As a result, the workshop sometimes ran out of components while, at other times, too many piled up. As a consequence, workers had nothing to do on some days and on other days had to work over eight hours to catch up. The stress and fatigue of such long hours meant that quality became uneven on these occasions. Apart from that, even though some quality problems appeared, as long as they were not too serious, workers as well as their managers would not like to stop work, because their salary was also linked with the quantity of their work, according to the new salary system.

It was very hard to solve these problems within the firm, given the lack of development of production technology and production systems. This must be understood in the context of the 30 year history of Chinese socialism, in which people had got used to Mao's idea that: "Ants can move Mount Taishan", and "The more people and the higher inspiration, the better the thing will be". Along with a system of non market competition, this left the industries of the country with underdeveloped production organisation, including adequate production means, technical design of the production process and the production management. In LTEF, when HJD-04 production was started the assembly procedure had to be completed manually. The practice taught the firm that (as was described by the new manager of the Department of Quality):

> The HJD-04 production is technology intensive. Its quality is not visible and tangible. You just can't expect such a technology to be made by hand and be of a good quality. This is in complete contrast with the traditional idea: 'The more people and the high inspiration' can't do any good to product quality. We've got to have an automated production process. In assembling components, anti-electrostatic measures are necessary. The fewer the people involved, the better the quality of production. Besides, while the degree of integration of printed-circuit board gets higher, soldering on it by hand

> becomes more and more impossible. Automation is the only and best solution, whether we like it or not (The head of the Department of Quality, 27.4.1993).

LTEF could not afford automation in the workshop. It was PTIC which successfully lobbied the government, and obtained the financial support for the purchase of the facilities needed, as already mentioned in section 6.2.3. All machines were to be shipped to the workshop in July 1993. The firm was looking forward to it, at the time of my visit.

The manager of the Department of Technology was still worrying about the management of the whole production process. He realised that the firm's capability of technical design for the production process was weak. The final documentation of technical design for the whole assembly procedure had not been completed by April 1993. Shop-floor workers were not used to strictly following documented instructions. Taylorism was never fully applied in socialist China; instead, workers were usually encouraged to complete a piece of work in their own ways as long as they could complete their job. For example, ten different workers might drill a hole in a piece of work in ten different ways, rather than following a standardised procedure. Obviously, this could not meet the standards of mass production of the HJD-04 system. The manager pointed out:

> In the past, technical design of production used to be considered less important than the design of product itself. This was common all over the country. As a consequence, innovations of production technology used to be considered less significant and, worse, technologists working on the production process were easily ignored. Because of this, we now lack technologists and expertise on production organisation. We have to learn gradually. It takes time; it's not easy (Head of the Department of Technology, 27.4.1993).

The internal institutional reform transformed the Department of Technology. The department laid down new operating rules for workers, tightened the procedures in the workshop. In order to speed up the improvement of production organisation, the firm raised the salaries for all in this department, and allowed the department to recruit technologists from different sources, as many as were needed. "I have been working in the area since the 1960s, for me, the change is remarkable", noted the head of the Department of Technology.

By contrast, the head of the Department of Quality who was not satisfied, could not help complaining:

> Till now, many of our managers are still sticking on the old thought that quality control is only the responsibility of our department. Each department for different reasons tries to cover up quality problems rather than put the problems on the table and track down the sources so as to root them out. We lack co-operation between departments and sections. Apart from this, pressures come from PTIC which asked to produce 25,000 lines this year [1993]. When production 'quantity' becomes critical, 'quality' can only be left behind. You know, we have got too many problems, and new machines have not arrived yet (The head of the Department of Quality, 27.4.1993).

"Product quality" can only be the result of a successful process made up from the combination of every piece of qualified work done by each worker. The experience of LTEF shows that this capability takes time to build up with respect of expertise of quality control and know-how of production organisation, as well as qualified workers, technicians and engineers.

The firm had been strengthening its technological capability with regard to production, installation and maintaining capability. Between October 1992 when HJD-04 technology was put into production and April 1993, about 80,000 lines and ten systems had been produced and installed.

6.4.3 Marketing

To sustain its financial situation and expand the domain of the HJD-04 system, the firm was doing its best to produce as many systems as it could.

Since the reform, LTEF had been enhancing its marketing department. There were over 20 sales persons in the department. They were sent away from home, travelling around the country for more than 200 days a year in average. The company encouraged them by offering a higher bonus which was related to the number of lines they sell. According to the manager of the marketing department, the average income in the department was 30% higher than the whole company. The new approach was expressed strongly by the former head of the Directorial Office of the PTIC:

> Now, firms are allowed to use material incentives, for instance, a good salesman, if he sold 100,000 line system, why shouldn't we give him a certain commission fee. In the new commercial economic environment, we should not keep the idea of 'iron rice bowl'. Those who contribute more to the firm, must

> be paid more, more than expected (The director of Beijing Long-Term Data Technology Corporation, former head of the Directorial Office of the PTIC, 6.4.1993).

This would not have happened in the past, because people were taught by a socialist dogma that each job must be treated equally, as long as it was for the revolution. A gate-guard would not necessarily be paid less than a engineer. Income differences between different professions were never that big. In LTEF, since the reform, such differences have been gradually widened.

As mentioned above, because the PDSS market was so big, there was considerable scope for the HJD-04. However there was one problem that some foreign governments were providing soft loans which in most case were for the purpose of supporting their own country's exports. Since many Chinese local Posts and Telecommunications Administrations had been operating at a loss and were not able to afford any PDSS, and the MPT was also short of finance, foreign soft loans had become an important source of finance. Having been offered this, recipients might be forced to buy foreign products as a precondition. Local administrations preferred using these loans to buy an expensive foreign system to buying a cheaper Chinese one. This involved two considerations. First, if it was a 20-year deferred loan, the official who took out the loan would not be in that post when the time comes to repay them. Second, purchasing a foreign system might well mean a free tour abroad for some officials!

However, there were opportunities for HJD-04, considering that, first, applying for soft loan takes time and the result was not always positive; and, second, even if it is successful, buying in foreign system may be slow. Since profits in the telecommunications service were very high, the investment could be returned in a short time. In this circumstance, buying HJD-04 was also a reasonable option.

In order to compete with foreign products, LTEF introduced some new policies. As some users were too poor to afford this product, LTEF made its payment policies more flexible, and even allowed some to pay less. LTEF had been holding information exchange meetings with current and potential users about one to three times a year to introduce HJD-04 technology to them, to collect feed-back from users and, in the meantime, sell its products. For this, it made a substantial expenditure, including arranging banquets and tours for all participants around the historical spots of the city of Luoyang in order to build and maintain good relations with users. This was impossible in the past, because of state regulations over accounting at firm level. Even corruption was used as a means of selling its system. It had arranged long distant tours, for local Posts and Telecommunications Administration officials in charge of purchasing the switching system, to different places around the country, some tour even further to Hong Kong, Thailand and so on. These expenditures were then added on to the cost of the system sold. The director of the firm commented about this with sorrow:

> It's not the way we would like to go deep in our hearts, but it is a way against 'no way'. We have so many mouths to feed (The Director of the LTEF, 22.4.1993).

In the recent period, marketing in China had involved many complicated factors. LTEF's behaviour had been led by the reality of and the requirements from the market.

With the effort made in marketing, LTEF's exchanges were currently operating in seven provinces, including in the far north, Jilin province and Inner Mongolia, in the west, Yunnan and Sichuan provinces, and also the neighbouring, Shandong province and the home province, Henan. The firm was very proud that two systems with 20,000 lines had been installed in Shenzhen, the most advanced economic zone next to Hong Kong.

6.4.4 Co-operation with Others

Technological innovation in the production process also demands co-operation between R&D institute and industry. In the past, under central planning firms could get fully technical support from R&D institutions in accordance with state plans without any condition. Therefore, firms like LTEF were not familiar with the new type of co-operation in a context of production for profits. The co-operation with the CIT and PTIC was such a new experience for LTEF that they were sometimes confused, as described in previous section. When the three were working together on the HJD-04 and to gain official approval, the things important for co-operation, e.g. a written document with detailed items to clarify and guarantee responsibilities and profits of each side, were overlooked. But, after the technology had shown its great potential in the market, they had to face the problems and conflicts emerging between them.

It made LTEF really uneasy that the core technology was held in other people's hands: for some things LTEF had to ask for CIT's instructions, and for others, it had to ask PTIC. Notwithstanding thus, the firm had to work together with CIT, as the system was still new and there were many adjustments to be done. Problems small and large arose frequently, especially, in the installation field. Similarly, LTEF needed the help of PTIC in many aspects. This did not rule out LTEF's intention to reduce its dependence upon CIT and PTIC. The establishment of the research institute by LTEF was such an effort. It was not that simple, that LTEF had decided to strengthen its technological capabilities. It gathered its best manpower in the research institute and gave them privileges in terms of better working conditions and higher rewards as well as living conditions. Although the firm's provision, in material sense, was far from the best, the firm intended to make these people feel their future would be promising.

However, to master entirely a technology like HJD-04 is not a matter of short-term endeavour, and may not be possible under certain conditions. As the firm was engaged everyday in dealing with urgent problems arising in workshops or switching offices elsewhere, these engineers could not help functioning like a fire-brigade. They worked 14 hours a day on average and even often over-time through the night. This situation did not allow them to engage seriously in any research work. Despite the firm's ambitions to, one day, master the entire technology of HJD-04 and be able to extricate itself from the external technological control, it remained under immediate pressure to improve production. Although LTEF was the most successful producer in general amongst all HJD-04 producers (both MPT and non-MPT), the quality of its products was still poor according to CIT. From the CIT's point of view, LTEF should concentrate on production organisation and product quality, and leave technological innovation to CIT.

As mentioned in section 6.3.1, LTEF was also very worried that the other HJD-04 producers would become strong rivals. The desire to prevent technology leakage to these firms made its relationship with them very sour. As one producer, which once ordered one lot of racks from LTEF, complained, LTEF was so nervous that this company might steal its technology of rack design and production, that it was reluctant to supply this company any racks of good quality. As the result, that lot of supply was not usable.

6.5 The Local Shaping of the Artefact - the HJD-04 System

HJD-04 technology was shaped by the particular social, economic and technological context in which it was developed and used, as well as by global developments in information and computer technology and PDSS technologies. The development of the Chinese HJD-04 system reaped benefits because its developers adapted existing technology without going through some of the developmental stages which preceded them in advanced industrialised countries. The HJD-04 was not a new technology in the strictest sense. When the development project started in 1989, many foreign PDSSs had already been introduced in China. R&D for most of the major PDSS technologies in the world started in the 1970s. By the end of 1989, these systems had been updated and were more sophisticated. The R&D for the Chinese system HJD-04 was built upon studies on several different advanced foreign systems, so it could integrate their advantages while avoiding their disadvantages. Moreover, by then, many software design tools could be purchased on the world market and many advanced electronic components (such as micro-processors) were available cheaply. There was thus no comparison between the development of HJD-04 and the earlier PDSSs, which had to start from scratch.

As noted earlier, the R&D project for HJD-04 was carried out by computer technology experts without a background in telephone-switching technology. This came up with a system with a comparatively simple structure. The system utilised cheap imported micro-processors: for example, the MC68000 micro-processor cost only 70-80 Chinese yuan each at that time. CIT's computer specialists were able to make a full-scale HJD-04 system, incorporating 1900 microprocessors, at a reasonable cost. The whole system only took about 2.4 Mb memory, while its software was packed on to only two diskettes.

As a late comer, the HJD-04 had several special features. Significantly, its switching network consisted of a single time (T) switch. This is a "duplicated T switching network", which is non-blocking with respect to call processing. The switching network consisted of up to 32 identical, relatively independent modules. The number of modules depended on the size and traffic requirements of a particular switching office. Its architecture design allowed a big processing capacity. Each switch module was capable of handling a traffic load of up to 360 Erlang with a processing capability of 2 million BHCA, whereas the average of the other PDSS systems was 1.2 million BHCA. If a switching office was equipped with 30 modules, and the average traffic-per-line was 0.18 Erlang[22], the switching office could handle 60,000 equivalent lines. This capacity was large enough to meet most switching office requirements in China; it was equivalent to that of a business environment in North America. Additionally, the structure of each module was identical, and interconnection between modules was via cables linking the buffer memories of each module. This design allowed for extensive office expansion, since the modules could be located anywhere within the pre-defined distance laid down in the design specification. (Chen Junliang, 1993)

The HJD-04 system was not as sophisticated as advanced foreign systems. However, its development had kept pace with major user demands. The process of technological development were shaped by the exigencies of the market. Because of the constraints of time and finance, the project could only concentrate on those features necessary for the basic functions of a switching system which were required by majority of its users.

The Chinese telecommunications market was as disparate as the nation's economic development - that is to say, demand was increasing rapidly in the south and east coast areas and big cities, while remaining very low in the west and especially the countryside. In advanced areas, users demanded sophisticated services while in less advanced areas, users required only the simplest adequate telephone lines. The specifications laid down by MPT had not requested advanced functions such as ISDN

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[22] Units of communications traffic. Defined as the average number of calls existing simultaneously

and IN. Although many advanced systems installed in China had such functions, they had not been used by then. The HJD-04 project was planned in accordance with this reality: the use of No.7 signalling system would be realised by the end of 1994, whereas ISDN and IN capabilities would be completed within the following few years, in line with user requirements.

Apart from flexibility, another target of HJD-04 was to keep its price low, in order to compete with advanced foreign systems in the market. In spite of the inefficiency of production in state-owned companies, and unfavourable tariff status until the end of 1993, the price of the HJD-04 was still lower than foreign PDSSs. Of the many foreign PDSS systems, Japanese ones and System-12 produced by Shanghai Bell were slightly cheaper than the others. Still, System-12 costs over 1,000 Chinese yuan per line, whereas the HJD-04 was currently about 850 yuan.[23] As had been planned, when the volume of production increased, the price would decrease and, when the import tariff was waived, it would no doubt fall further still. In addition, when buying System-12, users had to pay part of the price in foreign currency; this did not apply with HJD-04. Foreign systems were simply too expensive for low-level users and they were, in any case, not necessary in terms of local demands.

As a Chinese developed system, the HJD-04 design had been targeted on local network conditions and requirements. As indicated in section 5.3.2, in China, transmission quality and transmission lines varied greatly in different areas. The lower the network level, the poorer the conditions were. Foreign systems were rarely able to work under these circumstances. In addition, because of the combination of low telephone penetration rate and high demand throughout the country, most telephone lines were located in public services and each telephone set was used very intensively. Many foreign systems were designed around presumptions of lower usage of lines and had run into problems in this situation, sometimes even leading to the break-down of a local network. The HJD-04, with a processing capacity of 2 million BHCA, was designed to overcome this problem. Apart from that, the HJD-04 screen menu was in Chinese, whereas all foreign systems used English. In big cities, it might not be

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[23] This is according to my interview with manager of Sales Department in LTEF in April 1993.

difficult to find operators who could understand English (section 5.3.2). To overcome this, the HJD-04 system had a simple interface/outlet between operator and the machine set which made the system easy to run.

While all foreign companies were aiming at large cities, the Chinese system was aimed at lower levels in China's hierarchical public telecommunications network. Apart from the three international gateways, there were five levels in the public network: levels one to four (known as C1, C2, C3, C4) were transit switches, and level five (known as C5) was comprised of terminal switches. There were eight level-one (C1) transit switching centres; 22 level-two (C2) transit switching centres were located in the capital cities of provinces or autonomous regions; level-three (C3) transit switching centres were located in each district; level-four (C4) were located at the county level; and level-five (C5) terminal switches were located in every major city and town. The HJD-04 system could be used at C4 level or lower (although technologically it was designed also to meet the requirements at C3 level). It had a capacity of approximately 30,000 subscriber lines and could be used as local or tandem (toll) switches. Up till 1993, the C3 and higher levels were dominated by foreign systems. However there was a large market for the HJD-04 at the lower levels, which foreign systems either had not yet focused on or had difficulties in entering, because of the poor network conditions.

The HJD-04 developers developed a market strategy targeted on the large market for smaller C4 and C5 switches - its modular design allowed exchanges to be supplied according to the local capacity requirements (and expanded as demand grew). Within this strategy, the further development of the HJD-04 was planned as a remote terminal module. This would be very suitable for exchanges in the countryside, where telephone stations are scattered and the density of the network is low. To aid diffusion into these areas, it was intended that the suppliers would take responsibility for training operators and maintenance technicians on behalf of users. Since most of these areas had poor transportation, which made it inefficient to send service engineers to solve problems in person, users were allowed to adjust some software data in their local office when necessary.

6.6 Summary and Conclusion

The HJD-04 system emerged as a particular product of the social and economic environment in China during the transitional period. Political and economic pressures led the CIT military research team turn to civil technology, and Professor Wu's personal experiences drew his attention particularly to modern switching technologies. These initiated the development project. However, to develop a Chinese PDSS, it required: a) computer technology expertise; b) first-hand knowledge of switching technology; c) finance and political resources. Later on, the broader social context was again important. It drove CIT, Posts and Telecommunications Industrial Corporation (PTIC) and Luoyang Telephone Equipment Factory (LTEF) into a three-party coalition. With their respective strengths in financial, political and technical field, the three made an effective collaboration together.

The process can be seen as involving two phases. In the stage of technology creation, the project was unstable and vulnerable in the face of uncertainties and difficulties (relating to both the technological and administrative aspects). The three parties worked hard together to overcome technical and financial problems, and to appeal for regulatory approval from, in particular, MPT. However, once the development project succeeded and its potential market was recognised, the search for profit came to the fore. In this stage, tensions developed between the parties and new conflicts began to undermine the co-operation between them. Nevertheless, common interests still ultimately bound them together.

We can see that, during this process, the changing behaviour of individual parties was significantly shaped by the broader social, economic and political environment of China's transition. MPT's attitudes, state policies and technology users' interest, as well as the development of market mechanism, all played roles in this process.

The contributions of economic reforms to this technological development have been at least twofold: bringing in advanced technologies from abroad, and introducing the market mechanism. The latter created the environment for integrating technological development with economic development, which brought in pressures as well as incentives for R&D institutes, firms and organisations like PTIC to seek new technological opportunities. This development project *per se,* and the general type of co-operation among these three parties, are newly emerging in the transition. The PDSS was a relatively complex technology, and its development project required many different kinds of technical expertise as well as large financial investment and regulatory approval; a development project like this, initiated outside of state arrangements, had rarely happened in the past. Similarly, the type of co-operation between CIT, LTEF and PTIC was certainly a new phenomenon in the country. So were the problems and difficulties they encountered, and the conflicts between them during the development process.

The way in which the sociotechnical constituency (see Molina's approach described in chapter 3) of HJD-04 technology was built exemplifies the new institutional relations offering greater technological dynamism which are emerging in society with the introduction of market mechanisms. However, this gives evidences that market competition is the two-edged sword. On the one hand, it compelled firms and other agents relevant to technological activities to seek technological opportunities and co-operation, encouraging technological changes in line with local demands and strengthening indigenous technological capabilities. On the other hand, it put pressures on them to keep technology secret from each other and therefore damage inter-firm co-operation and co-operation between different technical and social agents, which were necessary for further technological innovation.

A state-owned firm like LTEF was pushed into organisational reform and a continuing technological learning process. Even some corrupt measures were adopted by LTEF in reaction to the emerging competitive market economy to survive in the new system of China's transition. As the previous traditions had not been completely removed and the new mechanism was still in the process of developing, many confusing elements arose, in the course of transition, e.g. an incomplete legislative system for protecting intellectual property rights or established markets for technological collaboration. As a result, the process of building up indigenous technological capabilities at firm-level proved to be uneven and unstable, heavily dependent on the contingencies of its particular setting and broader social changes.

The state proved to have played an important role during the transition period in many aspects. This case study suggests that the Chinese government's policies were essential in promoting PDSS technology development. Buying in and transferring advanced foreign technologies, meant that domestic technology was able to start from a higher base line, whilst it provided opportunities for Chinese to accumulate knowledge of different public digital switching systems. The government policy of decentralising financial control in telecommunications construction facilitated this process. In addition, more sophisticated foreign technologies set standards for local technology development, whilst the existence of local technologies on the market reined in the price of foreign products.

Because that, as noted above, market forces are a two-edged sword, the individual firm's interest might produce negative elements for wider co-operation. In such cases, government intervention in general is crucial to introduce measures for enhancing the linkage between R&D institutes and industries, and for completing the legislative system relevant to ownership of technology and regulating market competition, and to the best use of available material and human resources within the country. As the LTEF case shows, technological capabilities in the firm were still at a very basic level, some of the key issues related to labour development, changing people's perception of product quality, getting proper production equipment, developing routine quality control procedures and etc. Without the co-operation with CIT and PTIC, LTEF would have not been able to develop any PDSS like HJD-04.

State intervention in controlling the pace of economic reform was also necessary. As the LTEF case shows, the large scale of labour redundancy of state-owned firms in pursuing high productivity might have serious consequences.

From a technological point of view, HJD-04 had unique features, shaped by both social and technical elements involved in the development process. The most obvious "sociotechnical" features of HJD-04 includes the special composition of the R&D team, which consisted of CIT's computer designers and LTEF's switching technicians; their knowledge crossed computer techniques, switching applications in Chinese telecommunication network and MPT's specifications of it. By obtaining advanced technological information, development tools and cheap standardised electronic products (components) available in the international market the local development of PDSS like HJD-04 was made possible. The convoluted process of development in the context of economic and social transition, including factors such as the financial, market, cultural and political context, was embodied in the main features of HJD-04 which were adapted to local needs. Thus, it was capable of handling a dense traffic load - a challenge which had caused break-downs of many foreign systems used in China. It had a simple machine-operator interface, a Chinese-language screen menu and a flexible maintenance strategy. In addition, its development had been in line with users' requirements for low prices.

So far, the process of building up the sociotechnical constituency of PDSS HJD-04 had been completed in a relatively short time - from November 1989, when three parties all agreed to develop a full-size PDSS, to October 1992, when the technology was put in production and its technical features were able to meet the needs of the majority of its users. The case suggests that it is possible for a developing country to speed up its technological development by reaping benefits from existing overseas technologies. Although the Chinese HJD-04 system was not as sophisticated as advanced foreign systems, it was more appropriate for the unsophisticated condition of the Chinese network, and much cheaper. This raises issues about the strategies of utilising foreign advanced technological capabilities, to build up indigenous technological capabilities through effective technology transfer which we shall return to in chapter 8.

Another closely related issue is a national system of innovation. We have concluded that the current success of HJD-04 development and the collaboration (and conflicts) between CIT, LTEF and PTIC were associated with the broader social context in China which has been transforming from a centrally planned to a more market oriented economy. The question remains, whether the further development of the Chinese HJD-04 system will be able to keep pace with technological development, and the rapidly changing market. The further innovation of the Chinese PDSS depends largely on co-operative effort of many agents relevant to the technological activities in the whole country, as well as on the improvement of production capabilities at the firm level. The problems facing the three parties involved in HJD-04 shows that the future remains unpredictable, even though the market is large and growing; it is uncertain whether the social and economic transition in China will continue to improve the technological dynamism of the entire system. These issues will be further explored in chapter 8.

A Postscript

In August 1997, four years after the fieldwork for this study ended, and when writing up and analysis of this thesis was substantially completed, I visited China and was able to obtain some additional information about the Chinese telecommunications industry. Two news stories in particular threw light on the subsequent development of the Chinese PDSS industry:

China Daily, 28 August 1997: pp.3

> ... The production of HJD-04 Programme Controlled Switchboards by our country has changed the situation of the domination of imported switchboard in China. The national Switchboard industry made a breakthrough and has realised the exportation of switchboards made in China. (sic)
>
> As a leader of national switchboard production , GDT [Great Dragon Telecommunication (Group) Co., Ltd.] has sold ten million lines of HJD-04 programme controlled switchboards. ...

People's Daily - Overseas Edition, 8 September 1997: pp.2

> ... Now, PDSS products developed by ourselves [Chinese] have achieved a market share of 14%. Last year, over 5,000,000 locally developed PDSS (lines) were installed, and amongst the total new exchanges installed in the local telecommunication networks 23.4% were locally developed ones. ...

Although it was not possible to investigate these matters in further detail, it would seem that the hitherto fragmented HJD-04 production facilities have been reorganised with the support of MPT, MMEI and central government, united under a new banner Great Dragon Telecommunication. This group seems to have been successful in overcoming the production and marketing difficulties that threatened to hinder the prospects of the HJD-04 system. Indeed the Chinese developed PDSS has achieved remarkably rapid and high rate of penetration of the telecommunications market, particularly in local exchanges. I return to these points again in chapter 9 in relation to future research (section 9.8).

PART III: ANALYSIS AND CONCLUSIONS

Chapter 7:

Acquisition of PDSS Technological Capabilities through Utilising Foreign Advanced Technologies

7.1 Introduction

As discussed in chapter 2, this study explores how developing countries can accumulate indigenous technological capabilities and the contribution to this of the advanced technology transfer from abroad. The key for success is effectively utilise exogenous technological competencies. There are a range of different strategies and choices in selecting particular technologies for transfer and particular types of technology transactions. These choices may also depend on the objectives and requirements of the developing country - for example, what level and type of competence is needed? Is innovation competence required as well as productive capacity? Is there a difference between long and short term goals?

This chapter examines these questions in detail through a comparative analysis of how China has acquired PDSS technological capabilities by utilising advanced foreign technologies in two cases, System 12 and HJD-04. It comprises five sections. Section 7.2 analyses the different strategies represented by the System 12 case and HJD-04 case, and contrasts their strengths and weaknesses. This analysis mainly focuses on how the characteristics of the different technologies and the type of transfer processes affect the possibility for the Chinese to gain access to appropriate foreign advanced technologies. It also examines the scope for local shaping of these technologies, then how these two strategies worked in different circumstances during the Chinese economic reforms.

In the light of these two cases, section 7.3 analyses technological learning activities, relating to various formal or informal means for technological learning and important roles played by different technological agents, including technology producers, component producers, technology developers as well as switching technology users, in the learning processes. It also stresses the importance of the wider social and economic context and its impact on the effectiveness of the learning activities.

Section 7.4 examines the outcome of technological learning from exogenous technological competencies in relation to the accumulation of indigenous technological capabilities and the contribution to the Chinese telecommunications infrastructure. It distinguishes indigenous technological capabilities at the firm level from those at national level, and highlights the gap between Chinese technological capabilities and technological capabilities of individual firms' like Shanghai Bell and LTEF. Here it distinguishes two level of technological capabilities: at the basic level, of operational capabilities, e.g. production, services, marketing, resources allocation and management; and capabilities for creating and innovating PDSS technologies.

Section 7.5 draws the analysis in the preceding sections together in order to reach some concluding points. These relate to some of the research questions raised in chapter 2:

- How has China strategically utilised advanced foreign technological competencies in the area of public digital switching system to fulfil domestic demands for modernising its telecommunications infrastructure in short term and innovating the technology in the longer term?
- Have China's attempts at technology transfer been effective in terms of acquiring technological capabilities? Have they succeeded in using existing capabilities and, through technological learning, further accumulating them?
- What factors were crucial in establishing the technological learning needed to transform exogenous technological competencies into indigenous ones?
- What are the differences between the two strategies of technology transfer and indigenous technological development, in respect of selectively utilising foreign technologies and the scope of local shaping of these two systems?
- How has the combination of these two strategies served the country's requirements in the reconstruction of the telecommunications infrastructure and the acquisition of PDSS technological competencies?

7.2 Selectively Utilising Foreign Technologies - Contrasting System 12 and HJD-04 Cases

As discussed in chapter 2, the nature of imported technology and the type of technology transaction together determine both the availability and appropriability of exogenous technological competencies embodied in imported technologies, and the scope for local shaping of these imported technologies. Recipient countries can use different strategies for utilising foreign advanced technology to meet domestic requirements. This includes selecting different range and type of technology, e.g. between "system technology" and "component technology" and different types of transaction, e.g. wholesale technology transfer and the purchase of finished products.

This section compares the two contrasting strategies. The former involved transferring a comprehensive package of "system technology". The latter involved purchasing standardised "component technologies" as building blocks to develop Chinese system. This section analyses the weaknesses and strengths of these different strategies presented by the System 12 and HJD-04 cases. Section 7.2.1 explores their differences as a means of gaining access to the advanced technologies embodied in the imported technologies in terms of the availability and approriability of foreign technologies. Section 7.2.2 analyses the scopes for local shaping by using different strategies, followed by section 7.2.3 which examines how these strategies have helped to develop indigenous technological capabilities and meet the Chinese domestic requirements.

7.2.1 Different Approaches - Comparing System 12 and HJD-04 Cases

The System 12 case is an example of utilising foreign advanced technologies. But so paradoxically is the HJD-04 case (which in other ways was an indigenously developed PDSS). However, these cases are very different in many aspects. First, drawing on the theoretical framework developed, we can see that the artefacts imported in these two cases have very different characteristics. System 12 can be characterised as a "system technology" although it has application layers which are configurable, and the foreign technologies that the Chinese system HJD-04 comprises are "component technologies" (section 2.4.3). A "system technology" involves complexes of elements which mutually condition and constrain one another and which has its unique proprietary architecture and elements. A "system technology" like System 12 involves a wide range of foreign components, e.g. LSI chips, micro-processors and the other components, which had already been configured into a particular architecture before being transferred into China. These artefacts embodied foreign developers' technological, social and economic knowledge and rationales, and reflected their technological competencies which had been accumulated over time. This is in sharp contrast to "component technologies" which are generally designed to be used in conjunction with other technological elements, building on with standard interfaces, and are often available as cheap commodities in international markets (section 2.4.3).

Second, these two cases adopted different type of technology transfer transactions. System 12 is a wholesale technology transfer project, which included the manufacturing, engineering, and installation technologies, as well as skills of management. A highly formal and carefully planned process of technology transfer was adopted to ensure the transfer of all the skills needed to create in China productive capability for System 12. In contrast, the HJD-04 technology development project involved importing foreign standardised components as building blocks of the system, but the architecture of the system was designed by Chinese. In addition, software designing tools and some production facilities which China did not have were purchased from abroad. Exogenous technological expertise was thus acquired, embodied in artefacts - and artefacts that were themselves designed to be appropriable. This was supplemented by the informal acquisition by CIT of general knowledge of global developments with PDSS technologies.

A "system technology" like System 12 is much more difficult to master than the "component technologies" that the HJD-04 system is using. In the HJD-04 case, imported foreign standardised components could be used in building PDSS exchanges. It would seem to be impossible to master a technology like System 12, without a comprehensive package of technology transfer. Equally, wholesale technology transfer like System 12 almost inevitably requires a large capital input, whereas the standardised components are usually available cheaply on the world market. There is thus obvious scope for choice about the extent to which a country imports these components, rather than invests money and effort to produce them locally.

The availability of foreign technology depends largely on the way in which it is purchased and the means of technological learning. Buying finished foreign products obviously provides the least access to the technological competencies which are embodied in the artefacts and black-boxed before the delivery. Whereas wholesale technology transfer provides access to a wide range of technological capabilities spanning from knowledge of the artefacts to production and management techniques. Contrasting the two different approaches, clearly, the latter provides much better means than the former for the Chinese to gain access to advanced foreign technologies, which was carefully planned, negotiated and formalised in a written contract.

On the other hand, we can see that the wholesale transaction of System 12 production capacities allowed very limited technology creating and innovating capacities. Even the capacity to adapt System 12, needed to match the characteristics of the Chinese telecommunications system, was confined to the application layers. Moreover, its export capacity is also constrained as this would cut across BTM's interests in the world market (section 5.4.3). The Chinese HJD-04 case represents a very different model. Standardised foreign components and tools were purchased and used straight away in the design and production of the exchanges, without the need to obtain mastery over their design or production. Compared to System 12, the HJD-04 development required more creative effort on the part of the Chinese participants or actors, and so was better able to integrate the technical features of the system with local technological, economic and political requirements.

Another important difference between the System 12 and HJD-04 cases is that they were initiated in different stage of the economic reforms. The broad social and economic context surrounded these two cases were so different that the driving forces and strategies by which they built up their own sociotechnical constituencies were markedly different and required different approaches for establishing their own technological capabilities, and particularly in marketing, resource allocation and management. As the social and economic context is so crucial for technological learning, this will be discussed more thoroughly in chapter 8.

The final difference concerns the scope to shape and adapt the technology to meet particular local requirements, which differed substantially between the two cases. A technology, even a completed PDSS exchange technology like System 12, has to be adapted to meet the circumstances in which it will be used, and as noted both in chapter 5 and 6, the Chinese telecommunications system was a particularly challenging technical and social context. It is to this point we now turn.

7.2.2 Different Scope for Local Shaping of Technology

Both the nature of technology itself and the type of technology transfer transaction constrain the scope for local shaping. Contrasting the System 12 case and the HJD-04 case, System 12 as a system has much less scope for local adaptation than the design of a Chinese PDSS from an assemblage of imported discrete components with which HJD-04 is made up. The extent to which original technological elements were developed was clearly far greater in the design of HJD-04 than in the limited level of adaptation to local markets which took place in System 12.

Because of the complexity of public switching technology, its application package has to be customised to meet the requirements of the particular country. We have seen that Shanghai Bell had gradually overcome the incompatibility between System 12 and the poor conditions and un-standardised features in the Chinese telecommunications network - by, for instance, developing ancillary equipment to help System 12 identify signals from the telecommunications network and by customising the CDE packages.

However, in System 12, the space available for adaptation and reconfiguration is limited, largely within the domain of the application layers. The fact that the generic part of the system is shared by all System 12 producers and users across the world allows little chance for Chinese to make innovative changes of the technological core. We have seen that the further development of System 12 technology - either the system *per se* or its production technologies including equipment, process design and operation techniques - had hardly taken place in Shanghai Bell. Rather, such technological changes were carried out in the parent company, and then fed down to Shanghai Bell. The most significant local adaptation activities were limited to the area of customer application technologies and human-factor related management, e.g. the local development of some application software and the development of a distinctive hybrid management style in the production facility.

Since the generic technical features of System 12 were deeply embedded in its design, some of them could not be changed without considerable expense. For example, System 12 used the English language for operator-machine interface: in theory, this could be changed into Chinese written language but, because of the complexity of this technical task, it is not currently economical. Another example is System 12's limited capacity to handle the dense traffic loads, what are the typical situation in China, caused break-downs (section 5.3.2). This problem highlights the presumptions underpinning the technical design, which were to meet the requirements in industrialised environment rather than those typical of poor countries like China.

By contrast, building a PDSS from an assemblage of imported discrete components, as in the HJD-04 system, leaves great scope for local configuration. Professor Wu and his team were able to develop a Chinese switching system to meet the technological, economic and cultural requirements of the local environment and conditions for local production and operation, as well as international standards of telecommunications. CIT's core competencies in computer design, and LTEF's competencies in rack design and production and in understanding Chinese telecommunications network, were configured together with an array of available discrete foreign technologies - electronic components and development tools plus some foreign design concepts. As a result, HJD-04 is arguably the most suitable for the Chinese telecommunications network. It is also the easiest of the two systems to operate and maintain as it does not require operators who speak English. Being purposefully designed for the Chinese context, there is no problem of handling dense traffic loads. In addition, because the core technology is held in the hand of Chinese developers, for further updating and innovation is possible.

However, in the case of HJD-04, because of the type of transaction - purchasing of finished products, the technological competencies embodied in these products, e.g. component design and production technologies, are black-boxed. As there is no clearly defined access to them for recipients, thus virtually no scope for their local shaping.

On the other hand, there was little need to get inside these technologies. The microprocessors in particular offered generic technical functions that were rather clearly presented (price, processing power). They combined presumptions about their technical context that were largely standardised, but few specific constraints and presumptions about the application context. They could therefore be deployed as "black-boxed" solutions by the Chinese developers. In this sense, local shaping was restricted to the choice of processors available on the market. But that did not matter. These processors were readily available on the market as cheap and standardised commodities. As far as the Chinese developers were concerned, it was cheaper, simpler and less risky to buy in these technologies than seek to acquire local design and production competencies in building complex integrated circuits.

7.2.3 Different Strategies to Meet Domestic Demands

At the very beginning of the economic reforms, China lacked PDSS technological capabilities (both overall PDSS creation capacity and capacity to build constituent components) while domestic demands for adequate telecommunications infrastructure was pressing. The wholesale transfer of System 12 seemed to be the best solution under these circumstances. This project helped China to build up production capacity in PDSS from scratch, thus more or less satisfying the increasing domestic demands for modern telecommunications services.

The System 12 technology transfer provided formally defined means and a broad avenue for the Chinese to gain access to a wide range of advanced foreign technologies, ranging from component production to production management. The flow of technological information from industrialised countries to China through the System 12 transfer project was substantial. The later design of system HJD-04 had, to some extent, also benefited from this informal flow of technological information into China (section 6.2.2). Even in developing its production facilities and management approaches, LTEF sought help by sending delegations to Shanghai Bell to explore suitable solutions (section 6.3.1). Equally significant was that Shanghai Bell, through the domestication of component production programme, enabled transfer of advanced foreign technologies to local industries, creating components production facilities to meet world quality standards and technologies (section 5.5.3). In a sense, without the wholesale PDSS technology transfer through System 12 or a similar project, the indigenous technological development of HJD-04 might not have been possible.

However, a wholesale technology transfer requires enormous investment and resource inputs. The selection of the particular technology for transfer is very crucial. In the case of System 12, the aims of the PDSS technology transfer were very clear. China sought the most advanced technology and the latest version of its development and a technology which was suitable for the Chinese telecommunications environment. To ensure the transaction would provide China adequate means to obtain advanced technologies in both the short and long term, and limit technological dependency, it was important for the Chinese to insist on an experienced and reputable technology supplier and a comprehensive package of technology transfer including the specified LSI chip production at the heart of System 12. This was moreover a technological field in which China nationally was rather weak.

As discussed in section 7.2.1, System 12 technology is difficult for a developing country like China to master. To function properly, it also requires adaptation to the Chinese telecommunications environment. Because China's telecommunications condition was so poor, and because of substantial technological and cultural differences form Europe and North America (where System 12 development took place), this technological undertaking was very difficult for China. In such circumstances, the Chinese selection of the technology and the type of technology transaction involved a high risk of failure. The System 12 case confirms the enormous difficulties that Shanghai Bell faced particularly in the early stages of production and installation of the exchanges (for more details see section 5.3.2). Without powerful and sustained support by the Chinese government, the whole project of technology transfer would have failed.

The Chinese system HJD-04 might not be as sophisticated as System 12. However, it provides the Chinese telecommunications network with a PDSS which is able to meet user requirements that most foreign systems could not provide, in particular handling a dense traffic load. Compared to foreign systems, HJD-04 had a simple machine-operator interface, with a Chinese-language screen menu so as to be easy to operate. Because of its low development and production costs, the system offers low prices to Chinese users, which are particularly important to those in less developed areas and in rural areas.

Most important to China is the coexistence of a foreign PDSS like System 12 and a local one like HJD-04, which creates a dual development environment. First, foreign PDSSs are source of advanced technologies which are continually developing globally. Through both the international market and proprietary channel (e.g. BTM), Chinese companies (e.g. LTEF and Shanghai Bell) can keep in touch with the state of the art. Second, this provides a competitive environment, which, on the one hand, set up high standards for Chinese products and, on the other, rein in the price of foreign PDSSs and push further transfer of upgraded version of these technologies.

7.3 Technological Learning

As noted in theoretical chapter (section 2.4.2), technological learning is the means by which exogenous technological capabilities is transformed into indigenous technological capabilities. This section analyses how technological learning took place in the two cases. It looks into the means of technological learning, i.e. formally organised learning activities and informal technological information flow. It explores the importance of involving a wide range and number of players in technological learning, and the different roles that technology manufacturers, designers, users, component suppliers, etc. play in technological learning. In addition, it emphasises the importance of the wider social and economic environment in encouraging technological learning activities.

Substantial technological learning took place in both System 12 and HJD-04 cases. The range of learning activities includes formally organised learning, such as, staff and customer training courses arranged by both Shanghai Bell and LTEF; and the domestication of component production. The System 12 technology transfer utilised at least four different means for the Chinese in Shanghai Bell to obtain technological competencies: technological training, technical assistance from BTM's experts; BTM management participation, and the transfer of technological documents (section 5.3.1). Through these formalised means, the Chinese in Shanghai Bell have systematically obtained skills for manufacturing, installation and maintenance, as well as engineering technologies for System 12. Western managerial methods and values were also introduced into Shanghai Bell. This helped Shanghai Bell to develop its own strategies and policies for marketing, resource allocation and management. It allowed Shanghai Bell to achieve high productivity. As the production quality control is one of the most common problems in China's industry, the help of BTM's quality control specialist who at the outset set up the routines for Shanghai Bell to gradually achieve production quality at world level was critical.

Technological learning has not been solely confined to Shanghai Bell. Rather it has been widely spread through both informal and formal channels to System 12 users, component producers, and other related agents. The movement of Shanghai Bell's engineers to other establishments (R&D institutes, universities, firms, etc.) provided one means for the transfer of technological information across China. Many of the engineers and researchers who were gathered by MPT from across the country to help the System 12 project, later on returned to their original institutes, and thereafter, used their knowledge of System 12 to carry out some technological projects for Shanghai Bell (section 5.3.2). Some of them also contributed to the recognition of HJD-04 technology by MPT when they were involved in the examination for HJD-04 technical approval (section 6.2.2).

Unlike Shanghai Bell, in the HJD-04 case, technological learning was to a considerable degree through informal channels. Professor Wu, the key designer for HJD-04, acquired information about System 12 and other foreign PDSS through public available documents (section 6.2.2). LTEF sought information about production equipment and management through Shanghai Bell (section 6.3.2). Interestingly, it learned the importance of production quality through its *customers* whose quality standards for the Chinese system were set by foreign advanced products that had become available in the Chinese PDSS market. Apparently, market competition drove LTEF into an intensive learning cycle in order to improve its technological capabilities (section 6.3.2).

Informal and formal learning activities like these have taken place in almost all the players, involving not only those involved directly in the System 12 technology transfer and HJD-04 development projects, but also PDSS users, installation engineering teams (section 5.4), MPT's R&D institutes and the universities which helped Shanghai Bell to achieve System 12 adaptation and market expansion. More wide spread learning activities encompasses local industries, in particular System 12 component producers (see 5.5.3). The achievement of System 12 production capabilities required the involvement of a wide range of players within Shanghai Bell to inculcate not only understanding of manufacturing processes but also wider recognition of the importance of quality as well as production.

As noted in chapter 2, a supportive social and economic environment is crucial in providing incentives for technological learning. Without it, even formalised technological learning may be inefficient and incomplete. This was demonstrated in the case of System 12. The government organised domestication of System 12 component production was not very successful in the beginning, because Shanghai Bell and local producers lacked incentives. A very different situation emerged, at a later stage, when local production of System 12 components became in the interests of Shanghai Bell and local industries. Both Shanghai Bell and local industries were seeking co-operation opportunities, and local producers became active in technological learning to improve their technological capabilities.

7.4 China's PDSS Technological Capabilities

China was seeking not only to meet domestic demands for PDSS technology. As already noted, China had an objective ultimately to bring about accumulation of its technological capabilities. This study distinguishes basic level technological capabilities, such as, production, operation, maintenance, marketing and resource allocation, from higher level capabilities of innovating and creating new technologies. It also stresses differences in technological capabilities between the firm level and the national level. The two cases of System 12 and HJD-04 show that, from the view point of the entire country, China now possesses a wide range of PDSS technological capabilities, from creation, design to production, installation, operation and maintenance. However, individual firms are still in the stage of accumulating basic technological capabilities.

This section first examines the development of basic PDSS technological capabilities at both the national and firm levels. For firms, to be productive requires not just production technological capabilities, but also very basic capabilities in marketing, resource allocation, management, which allow them to survive in a more market oriented system in China today. Second, it analyses particularly the development of higher level technological capabilities in PDSS technology creation and innovation. Finally, it examines how the acquisition of PDSS technological capabilities through utilising foreign technologies has contributed to the Chinese telecommunications infrastructure.

7.4.1 Basic Level Technological Capabilities

The development of technological capabilities in PDSS production, operation and services in China as a whole was extremely successful, through advanced technology transfer from industrialised countries, in particular wholesale technology transfer. In the case of System 12, production capacity had expanded rapidly, from 15,000 lines in 1987 to 2,700,000 lines in 1993, during seven year's production (section 5.3.1). Shanghai Bell's productivity even out-performed BTM (section 5.4.5). Production capabilities for System 12 components have also been gradually established and upgraded, e.g. the custom LSI chips, an advanced technology in international terms (although quality was still a problem at that time).

As we have seen in both cases, the state of production technology in China was extremely poor, especially in design of the production, quality control, and production management. This backwardness stemmed from the old centrally planned system, and the weak links not only between technology designer and producers, but also with technology users. Most technology designers lacked a sense of commercial issues; producers were mainly "plan-takers" (section 2.3.1); and technology users were accustomed to having no choice but to accepting what producers produced. This situation has begun to change since the economic reforms and the introduction of market mechanism. We can see The manufacturing firms involved in both cases have gradually established capabilities in marketing and resource allocation, and have also been compelled by market pressures to improve production quality and efficiency. However, improving these basic technological capabilities is obviously a long term task - not least because it is associated with the whole economic system, and a wide range of people within it. For example, to ensure the quality of System 12, Shanghai Bell had first of all to improve the quality of each component when their production was domesticated. This required the effort of all local producers - i.e. for LED, resistors and even the screws used on the switches (section 5.5.3).

There are very few firms like Shanghai Bell possessing these basic technological capabilities at firm level. The both cases show that most state owned companies involved in either System 12 component production or the Chinese HJD-04 manufacture were still struggling to improve their production quality and productivity, and to build up from scratch their capabilities in marketing, resource allocation and management. Even LTEF, which can be considered the most successful and major producer of HJD-04 exchanges, still had a long way to go to catch up with Shanghai Bell. In April 1993, its production capacity was merely 80,000 lines, compared to Shanghai Bell's then annual capacity of 2,700,000 lines.

Given China's urgent need to modernise its telecommunications infrastructure and provide adequate telecommunications services to underpin rapid economic growth, development of production capabilities was arguably the most important priority for China at this stage and more immediately significant than developing the capabilities to innovate telecommunications technologies. The development of these basic production capabilities to overcome the poor state in the telecommunications and electronics sectors was necessary and could also provide the basis for higher level technological competencies in future.

The development of production capabilities required a quantum jump in production technologies in these sectors. No less important was recognition of the need to bring production quality in line with world-wide standards in terms of reliability and accuracy (both are particularly crucial for switching technology, but have a more general relevance). And this depended upon development of "non-technical" capabilities, such as marketing (including recognition of the importance of users requirements), production management and quality control and, crucially, understanding of all these issues by the workforce as a whole. To the extent that these objectives were attained, there was considerable scope for domestication of production - as demonstrated in the case of System 12 component supply. The Chinese domestic market is huge. And low Chinese wage costs could offset the weaker base in production technology, keeping Chinese production competitive with foreign supply.

7.4.2 The Capability of Innovation and Creation

Whilst production capacity had the most obvious immediate economic importance for a country like China, the indigenous capability to create and innovate technologies have been seen as more strategic in the long term in allowing China to avoid technological dependence on foreign firms and foreign market supply, as well as better to meet local needs. At the firm level, Chinese switch producers are very weak in terms of technology innovating capabilities. Even Shanghai Bell, the most successful PDSS producer, had limited activities in PDSS technology innovation. This is due partly to the model of System 12 technology transfer, and partly to China's existing technological capabilities. Moreover, Shanghai Bell was in the stage of rapid expansion of its production facilities, and its products were in constant high demand, it had little interest in pursuing major technological changes to System 12. Although LTEF was one of China's most modern exchange producers, and became one of the three key developers of the Chinese HJD-04 system, it apparently could not carry out any undertakings in PDSS R&D and design on its own.

However, China has developed its own PDSS systems through co-operation between R&D institution and industry. The Chinese HJD-04 system is the best example. Such a technological co-operation brought the technological capabilities in PDSS creation and innovation of China as a country to a high level.

The HJD-04 case displays the technological capabilities and ingenuity of Chinese developers, especially CIT who were able to combine foreign and local technological elements to create their own PDSS. The Chinese PDSS development took advantage of being later than that of other major PDSS technologies in the world, bypassed difficulties (i.e. leapfrogging) in PDSS design which preceding developers had been forced to confront, and reaped benefits from the available technologies. Most significant is that the Chinese developers were able to turned the technical challenges of development into the ones that they were good at. They utilised fully their strengths in computer technology design while by-passing their weakness in electronic components design and production. As a result, the HJD-04 has distinctive technical features. It is not a copy of any other PDSS technologies in the world through reverse engineering or the like. Rather it is a good system in many respects, and moreover appropriate for Chinese. The HJD-04 allows a large processing capacity, a challenge for most foreign PDSSs used in China, and is easy to operate and maintain. More essential, this system is simple and easy for Chinese to produce, given that production capabilities were poor in Chinese industries particularly in microelectronics. The Chinese HJD-04 is perhaps the only (or one of very few) PDSSs which was developed in as little as three-year's time, with the investment of only a modest amount of money, and was successfully developed by a small R&D team with only 18 people as fixed staff (section 6.2.2). Since the Chinese HJD-04 has a modules architecture and is designed to be open for future development, it allows Chinese developers to develop new technical functions such as the No.7 signalling system, ISDN, IN, etc. separately in line with Chinese users' requirements (section 6.5). This meanwhile keeps the R&D costs, and thus its market prices at a low level.

By all these criteria, HJD-04 is a distinctive success for Chinese. However, since HJD-04 is a late comer, compared to foreign systems like System 12, its position in Chinese PDSS market is far from secure and its production capacity is far too low. In addition, the system itself needs further sophistication, and the production technologies of HJD-04 need to be improved. These require further effort of designers and producers as well as management organisations like PTIC, and more investment in R&D and production equipment. In addition, China's economic system did not give manufacturing firms like LTEF any direct access to foreign component suppliers, which made stable production more difficult, let alone the many burdens which a state-owned firm like LTEF had inherited and still suffered from.

Technological collaboration between R&D institutes and industries is particular crucial, but these linkage have been poor as a result of failings in the central planning system, with the result that existing technological capabilities in China are still low in general and are particularly weak within manufacturing sector. In the HJD-04 development case, continued technological co-operation between CIT, LTEF and PTIC, as well as between HJD-04 producers under MPT and those under MMEI, was not secure at the end of the study (section 6.2.3). If the problem deteriorates, it may well shadow the future of the Chinese HJD-04 project and slow the pace of accumulating technological capabilities. This is a reminder of how the broader social context and the strategies of the players may inhibit the technological collaboration and knowledge flows needed for developing new technologies.

Although the System 12 technology transfer was not designed to deliver technology innovation competencies, or indeed could be said to have been designed not to deliver this, it did lead to the dissemination of PDSS technological knowledge across a network of players in the telecommunications producer and user industries and research institutes. They provided the basis for further development work on System 12 (and indirectly, could be argued to have provided a spring board for the later HJD-04 project).

Comparative analysis of these two attempts to develop PDSS technological competence suggest that there is not a rigid division between importing production competence (the focus of System 12 technology transfer) and indigenous technology innovation capacity (the focus of HJD-04). The two cases remind us that there are different routes to achieving technological capabilities. The wholesale import of production technological competence for a complete PDSS system (System 12) gave less scope for acquiring and applying innovation capabilities than the HJD-04 case, particularly in relation to the core technologies which were proprietary. However this did not prevent an important local innovation effort around adapting System 12 to Chinese circumstances. The Chinese HJD-04 development has been extremely successful in the way that it made selective use of imported technological elements - allowing the local developers to concentrate on those areas in which it was feasible and most advantageous to have indigenous development. There is considerable scope for such a selective approach, that can combine pragmatic and opportunistic considerations (as opportunities emerging from time to time in domestic and the world market).

Standing back from these two cases, it may be necessary to rethink earlier discussion of the "technological dependence" thesis with its implications that only indigenous technology innovation capacity across the full range of technologies involved could avoid such dependence. As these cases show, there are different routes for achieving technological capacity. It is possible to combine local technological capabilities flexibly with buying in foreign technological capacities through the market (in various forms - varying from component technologies to finished solutions and the facilities to make them). The proprietary core technologies (including a dedicated LSI chip) at the heart of System 12 did pose an important constraint. On the other hand, it was not clear to what extent it would ever be desirable to seek indigenous innovation capabilities for all the elements of a complex technology such as a telephone exchange. The growth of inter-operability standards and the marketing of cheap, commodified and readily applicable tools and components represents a challenge to the provision of technologies, (even complex large scale technologies such as PDSS exchanges) as finished "system" solutions. The configuration of such complex solutions from assemblages of bought-in and custom elements is likely to become increasingly common. In this context, technology innovation capability across the board is likely to be unnecessary. It may also be undesirable. It potentially increases the cost and time investment in a new technology. It may also encourage a segregation of network from global development - which in the long term may threaten local stagnation and loss of economic and technological competitiveness. The development of new technologies is becoming one increasingly global activity - particularly in the case of information and communication technologies with their potentially enormous development costs. Only the strongest and most advanced economies, if at all, could afford to "go it alone". Most countries (and all developing countries, surely) will be faced to resort to global markets as well as domestic development and production - thereby reducing the costs and risks of wholesale development.

And at the firm level, the continued involvement of overseas suppliers was seen as beneficial in that it kept Chinese firms in contact with global developments - not only in the HJD-04 case but also in the supply of components for Shanghai Bell. Technology production in a dynamic and global sector like CIT is likely to revolve around combinations of local production and resort to the global market.

The other way in which the dependency thesis may need revision is in its privilege of innovation over production capabilities. Despite the undoubtedly amazing achievements of the HJD-04 constituency, it still faced enormous problems in increasing production capabilities. And the limitations in technology innovation capabilities in the System 12 case does not seem to have been overwhelming and has not threatened the ability of Shanghai Bell from becoming the major PDSS supplier in China. More important here was competitive supply of PDSS technologies (between overseas provision, various joint ventures and indigenous producers) which kept product prices at a reasonable level. Though the perhaps implicit starting point of this these prioritised the acquisition of innovation capabilities over production capabilities - that does not seem to be justified by these cases. Acquisition of production capacity and domestication of component supply led to the widespread uptake of PDSS technological competencies in the Chinese telecommunications production sector and public sector research institutes. It also may on immediate and vital contribution to Chinese telecommunications infrastructure and it is to this point that we now turn.

7.4.3 Contributions to the Chinese Telecommunications Infrastructure

During last fifteen years of economic reforms (1978-1993), China had succeeded in both modernising switching technologies and increasing telecommunications network capacity dramatically. In the end of 1993, China's telephone lines reached 25 million, and the penetration ratio 20 phones per 1,000 people, compared to about 4 million lines and 4 phones per 1,000 people in 1978 (section 4.2). In terms of switching technology, China leapfrogged older vintages of technology, for example, analogue automatic switches. About 98 percent of the cross-bar switches in provincial capital cities had been replaced by digital computer programme-controlled switching systems. Many rural manual exchanges had been replaced by digital programme-controlled exchanges, and in some areas, first installation of telephone exchange directly entered the digital realm. These achievement in China's telecommunications infrastructure is prominent, considering both the rate of expansion and its poor starting position in terms of technology.

We can see it would not be possible to achieve such a quantum jump without introducing advanced foreign PDSS technologies. Along side with directly imported finished PDSS products, locally produced foreign PDSSs, such as System 12 by Shanghai Bell, EWSD by BISC and Neax-61 by a Sino-NEC joint production venture (section 4.3), contributed greatly to the rapid development of the Chinese telecommunications infrastructure, and helped to meet China's exigent domestic demands for adequate telecommunications services. In 1993, Shanghai Bell's share in the PDSS market was as high as 50% (section 5.4.3), let alone the other two joint PDSS production ventures.

Chinese PDSSs also played a part in the improvement of the Chinese telecommunications network services. Though small, this contribution was important. As the economic development as well as existing telecommunications network conditions in different areas of China varies to a considerable extent, many inland districts and rural areas lag far behind the coastal urban areas and large cities. Thus demands for telecommunications services from inland districts or rural areas often different from large cities. They are often not able to afford expensive foreign PDSS exchanges. Apart from this, because their local telecommunications network and other relevant conditions are usually poor, foreign exchanges are less suitable for them. In these circumstances, as Chinese PDSSs, such as HJD-04, which was designed to meet these local requirements, being low cost and easy to operate, etc., are able to cover these areas very well.

7.5 Concluding Points

The empirical case studies show that transferring foreign advanced technologies made a crucially important contribution to PDSS technology development in China. In the situation lacking indigenous PDSS technological capability, a wholesale technology transfer is recommended; arguably, the weaker the existing technological capabilities the recipient possesses, the more a comprehensive package of technology transaction is needed.

The key requirement is *selective utilisation* of foreign technology. Here two elements are essential: the type of technology and the type of technology transaction. These two elements determine the availability and appropriability of exogenous technological competencies which are embodied in the imported technologies. They also have an impact on the scope for local shaping of the imported technologies. The strategy used in the System 12 case can be seen as involving acquisition of a "system technology" which embodied a wide range of advanced technologies from the industrialised world, plus foreign developers' technological, social and economic knowledge and rationales. It established the wholesale technology transfer through various formalised channels to allow the Chinese to gain access to these technologies. In contrast, the strategy adopted in the Chinese HJD-04 development involved using foreign standardised components as building blocks to create a Chinese PDSS technology to fulfil local requirements. It also used foreign production equipment and software design tools which China was lacking at that time.

Selecting a "system technology" like System 12 seems to be a correct choice, given the circumstance that China badly needed PDSS technology at that time. Because a "system technology" is difficult to master, the selection of wholesale technology transfer was also necessary. As noted above, the transfer of a comprehensive package provided the Chinese in Shanghai Bell with access to virtually every technology of System 12. The weaknesses are that this strategy requires huge investment, and bring technical difficulties. As it requires tackling a wide range of challenges, particularly the production of proprietary LSI chips, there is high risk of failure, and so potentially of huge losses. Apart from this, because System 12 is a foreign developed proprietary system, some core technologies of the system are not appropriable by the Chinese (due partly to low existing technological capabilities and partly to high expenses and effort that Shanghai Bell could not afford at the moment). Because of the nature of the transaction, the scope for social shaping of System 12 technology is confined to customising its application layers and its export capacity is also very limited.

In contrast, by selecting the purchase of standardised "component technology", which is usually available and cheap in the world market, the HJD-04 developers by-passed the weakness of China's existing technological capability in electronic component design and production. At the same time, this allowed the Chinese developers to concentrate on the system design which the Chinese developers had strengths to meet local requirements, while leaving the technologies in component design and production to be black-boxed for the time being. As this is a Chinese designed system, it can in principle always be improved and innovated in line with the needs of Chinese users. Of course, to pursue this strategy requires indigenous PDSS technology creating capabilities, i.e. Chinese developers must possess adequate knowledge about digital switching technologies. Apart from that, the shift of the main technology of switching system from electric-mechanical to computer technology also provided a chance for CIT to get involved in PDSS technology design and be able to fully use its computer design expertise and apply rapidly upgraded technologies in electronics and computing to the Chinese PDSS.

It seems that the System 12 project has been very effective eventually in meeting the pressing domestic demands from the rapid economic growth and the modernisation of the Chinese telecommunications technologies and providing adequate telecommunications services. In addition, this project played a role as a source of advanced technologies which enabled flows of some kinds of technological knowledge more broadly across the country. To some extent, this strategy made possible the emergence of the HJD-04 project. Without the comprehensive transfer package of advanced system technologies like System 12, the Chinese system HJD-04 development might not have taken place. Thus it is the coexistence of foreign advanced PDSS systems like System 12 and Chinese PDSS technologies like HJD-04 which is most important for China. This has created a dual development environment, which allows two technologies to compete with each other. On the one hand, existence of the foreign PDSSs forces Chinese PDSSs to meet international standards, and on the other, the existence of Chinese indigenous PDSS technologies means that many features not available in foreign PDSSs can be developed to better serve Chinese users who have particular needs, e.g. low price, a simple system that is easy to operate and maintain and is able to work in poor local telecommunications conditions, etc.

There are differences between firm level and national level in terms of technological capabilities. In the light of both the System 12 and HJD-04 cases, we can see that China as a whole has now obtained considerable PDSS technological capabilities in a range of areas from production, engineering, operation, services to creation and innovation. Notwithstanding this, in general technological capabilities of individual firms are still weak, and in particular in local industries which are till struggling to improve their technological capabilities in production, marketing and management which are operational and basic for a firm to survive. To some extent, acquisition of these technological capabilities needed to produce and implement PDSS technologies are more essential than capabilities in creation and innovation, certainly at this stage in Chinese development. These capabilities are associated with not only a few extremely highly skilled and creative engineers and technologists, but rather involve a wide range of players including not only producers and technological specialists, but also users - and not only those within the same industry but also in other industries which are suppliers of materials or components or product consumers. In China, production capabilities at firm level were so poor, that the improvement almost has to start from scratch. Problems in production quality control and efficiency are still major obstacles for all Chinese industries. Firms like Shanghai Bell which have achieved high productivity and quality levels are few and far between across the country. Firms like LTEF are more typical among those in the state-owned sector. There is still a long way to go for Chinese firms to possess technological capabilities in creating and innovating technologies like the system HJD-04.

The System 12 and HJD-04 cases show the importance of technological learning, through which the Chinese could be able to master foreign advanced technologies, to adapt foreign technologies like System 12 to the Chinese telecommunications network, and moreover to create Chinese indigenous systems like HJD-04. Four elements are essential in the process of technological learning. First, formalised means are needed, e.g. technological training, operating with technical assistance, etc. Second, these are complemented by wider informal avenues for technological learning. Even making advanced technology products available through the market has given opportunities for users to compare different products and therefore learn what quality a user can expect. Third, mass involvement in technological learning is crucial particularly for improving firms' technological capabilities in production. Fourth, it is necessary to have an environment which creates incentives for technological learning. A supportive macro environment is so crucial for technological development, that is the other main concern of this study which we will discuss in the next chapter (chapter 8).

Chapter 8:

China's Changing Socio-Economic Context for PDSS Technology Development

8.1 Introduction

Chapter 7 left one very important issue to be discussed, which is essential to the effectiveness of utilising foreign advanced technologies and building up indigenous technological capabilities. This is also one of the two major concerns of this study - the wider social and economic context of a country in which technology development takes place. In the light of the empirical case studies, this chapter focuses on the link between technological development and the restructuring of the national system of innovation during China's social and economic transition from a centrally controlled socialist state to a more market oriented system. Two key elements have been crucial to the above issues, state intervention and market forces. As there has been long-standing debate about the issue of state versus market, this chapter will focus specifically on their roles in relation to the PDSS technology development in China.

There are five sections in this chapter. Section 8.2 examines the changes in the national system of innovation in China during the social and economic transition. Section 8.3 further explores the role of both the state and the market, in relation to the PDSS cases. Section 8.4 highlights the policy implications following on from the discussions in previous two sections. The final section, 8.5 sums up and presents concluding points drawn from previous three sections. In particular, it seeks to answer research questions raised in chapter 2 relating to the wider social and economic context in China where the PDSS technological development took place:

- How has China's transition - both the opening up of market forces and the changing institutional context - impacted on the development of PDSS technology?
- What implications can be drawn from the Chinese PDSS cases about the respective roles of state intervention versus market forces?
- What are the changes of the forms of state intervention of the Chinese government over time during the transition and their links to different outcomes?

8.2 National System of Innovation

Chapter 2 already pointed out the increasing interest within technology studies in the concept of "national system of innovation", addressing the links between technological dynamism and institutional structures and incentives for innovation. This section discusses how China's national system changed over time, from a rigid centrally planned system to a more dynamic one, during its current transition. In the light of the two empirical cases, it seeks to map out how the introduction of market elements altered the links between players involved in technological activities and generated incentives for them to explore technological opportunities, to engage in technological learning and, ultimately, to build up technological capabilities of the nation.

This section first looks into the problems of the Chinese socialist state in terms of its institutional structure and the incentives offered by the system for technological change (8.2.1). These problems were inherited from the socialist system and were deeply rooted, and state-owned firms like LTEF still suffered to this date from then. Section 8.2.2 explores how the introduction of market mechanisms in China has enabled new links to be developed between technology R&D institutions, producers and users, and brought about incentives to the system for adopting technological changes. Despite this, the analysis of the empirical cases shows that state intervention has also greatly contributed to the PDSS technological development (8.2.3).

8.2.1 Problems Inherited from Socialist System

China just as most developing countries lacks technological resources, and its technological capabilities in general lagged behind the Western world for centuries. However, while making this comparison at two different levels, the national level and the firm level, we can see that the latter is far lower than the former, which was also concluded in chapter 7. In the case of Chinese PDSS technology, the country as a whole has acquired considerable technological capabilities not only in production, operation and services, but also in creation and innovation. However, individual firms are still struggling for their basic technological capabilities from scratch, such as production, marketing, resources allocation, etc., needed for firms to survive in a more market oriented economy. The lack of basic technological capabilities of individual firms was deeply rooted in the old Chinese socialist centrally planned system.

As was discussed in chapter 2, from the view point of national systems of innovation, the conventional system of socialist states had two fatal weaknesses in relation to technological dynamism:

a) the central planning mechanism could not effectively link technology developers, producers, financiers and users;
b) it could not generate incentives in a regular basis for technological changes.

Under the centrally planned system, even within the same industry, the connection between R&D institutions and production firms was mainly through the planning system. R&D institutions worked according to plans. So did production firms. All their resources, including human, material, and finance were administratively arranged through specified state agents. So was the allocation of products. R&D institutes received technology development projects, together with the package of resources needed, from their superior managerial organisation. Their newly developed technologies were therefore freely transferred to production firms. In a similar way, firms received new technology projects, and accordingly their products were attributed to users at more or less fixed price by the state.

When users had no option, but could only get what firms produced, then users' sense of quality was suppressed. Without needing to face competitive challenges, producers had little motive to pursue technological improvement. Typical illustrations have been provided by the two case studies. For instance, were it not for the efforts of Shanghai Bell, the local screw producers would have never realised that its production quality needed to be improved. If it were not for the market mechanism, the electronics component producer under MMEI would not have realised that its existing production capabilities which were geared to producing components for the defence sector could not meet the demands of commercial production (section 5.5.3). These examples also reveal the fact that under the centrally planned system, the production design which was carried out in the laboratory often had virtually no connection with what real production and commercial requirements were.

These are all fundamental problems stemming from the central planning system. Because of these, financial resources might not go where they were the most needed and might not be used effectively. Even the best human resources in R&D sector might not be able to develop technologies that were appropriate for production sectors or for their customers. Manufacturing enterprises lacked capabilities in resource allocation and marketing, as they were not needed in the centrally planned system. Instead, because of the Chinese socialist tradition, firms (especially state-owned firms like LTEF) were encumbered with a substantial social function. These obstacles greatly constrained the development of production technology in the centrally planned system. No doubt, to root out these problems far reaching changes must be adopted across the entire system. Inevitably, this has to involve a wide range of organisations and peoples, from R&D institutions, manufacturing firms, financial organisations to users, and from technology creators, designers, managers, engineers to shop-floor work-forces.

8.2.2 the Introduction of Market Mechanisms

The empirical case studies have thrown light on the rapid changes occurring because of the introduction of market mechanisms. First, it brought about new types of collaboration between R&D institutes and manufacturing firms. As shown in the System 12 case, Shanghai Bell initiated technological co-operations with some local universities and R&D institutes on quite a few occasions. Equally HJD-04 was itself a successful product of technological collaboration between a military R&D institute (CIT) and a state-owned switching producer (LTEF), and an industrial procurement organisation (PTIC), the financial sponsor and the manager of this project. In particular, the latter case clearly demonstrates the emergence of a new type of collaboration that has brought in close links between technology creators (and designers) and producers and users. It demonstrated the benefits of such co-operation for product design: it enabled the design of technology to match the existing production capabilities; and its technological modification and innovation to be carried out on the basis of a better mutual understanding between designers, producers and users.

Second, the introduction of market forces has changed attitudes of organisations and peoples toward technological activities. As the HJD-04 case shows, none of the three key developers would have become involved in a project like HJD-04, without the socio-economic transition from the centrally planned to a more market oriented system. CIT as a military R&D institute would not have turned its attention to a civil telephone switching development project, as its research project was decided by higher military authorities. With the transition it was not only given greater freedom to modify its activities to exploit financial opportunities, it was also under pressure to achieve commercial development to safeguard its own economic security. Opportunity and necessity were combined to force many People's Liberation Army units to embark on commercial ventures. Similarly, as LTEF under the old system did not need to worry about its production output, it could produce its cross-bar switches for a long time without any changes. To a large extent, it was forced to explore technological opportunities under the increasing financial pressure given the rapidly falling demand for its existing cross-bar switches (section 6.3). The fact that PTIC as a newly established industrial unit of MPT became interested in this project was also because of the new phenomenon of market forces. Because technologies began to be commercialised, there was no longer any free technology transfer even within the sector (section 6.2.2).

Third, and perhaps the most important, is the creation of incentives in the system for technological learning, therefore leading to the accumulation of technological capabilities. As shown in both empirical case studies, firms like Shanghai Bell, LTEF and other local component producers have been compelled by market forces to master new technologies, to improve production management, to establish marketing skills and to allocate resources by themselves.

Although it was in the first place set up by the Chinese government and afterwards enjoyed privileges provided by the government, the new environment that Shanghai Bell forced itself in stimulated the firm to learn to segregate its own business interests from that of governments. On the one hand, it resorted to technical, financial and political support from the central government, MPT and the Shanghai municipal government, on the other hand, it rejected some interference from them which would cut across its best interests. It co-operated with government to rapidly expand its market share. Whereas MMEI wanted it to take the firm, which produced electronic components (at high production costs) for the national defence sector, to be the supplier of transistors and TTL circuits for System 12, however, Shanghai Bell refused outright. Managers in Shanghai Bell might all have been accustomed to state intervention in the old socialist tradition before they worked in Shanghai Bell, but they learned quickly in a more market oriented context what the company had to pursue. This was clearly shown by their interview responses (chapter 5, particularly quotations in section 5.4 and 5.5). Their technological activities, such as technology adaptation, domestication of component production, were selectively chosen, in order to pursue Shanghai Bell's benefits. Their learning of Western managerial methods was not a simple copying of BTM. Rather it developed a hybrid style of management between Western and Chinese methods through which it achieved high productivity. In marketing and resource allocation, local managers articulated Shanghai Bell's natural connections both domestic and overseas, and established specific measures and policies in customer training, staff recruitment, technical collaboration, etc. to maximise Shanghai Bell's profits (section 5.4 and 5.5). Without market forces, Shanghai Bell might have become another "state-owned" firm and would have not developed its capabilities in marketing, resource allocation and management, as it received government protection in many aspects from the outset.

Similarly, under high pressure from the new and changing environment, LTEF has been learning to build up its basic technological capabilities from scratch, although the process was painstaking, as it could not shake off all of these social burdens inherited from the past. However, it has been learning. Management learned to motivate staff to work harder in the new environment by reforming the administrative system, by setting up an internal labour market, etc.; to manage production and quality more efficiently and effectively; to have greater autonomy in allocating human, financial and material resources by its own; and to "marketise" its products by providing better quality products, services (and even adopt arguably corrupt measures) to win customers. It was signals through the market mechanisms which motivated understanding of customers' requirements of "quality", and set up criteria for producers like LTEF to achieve. In addition, in such a more market oriented environment, management and staff in LTEF were compelled to recognise the ownership of technology and the potential power and profit attached to technology. In addition to learning how to improve its basic capabilities, LTEF even decided to master the innovating technological capability by setting up its own R&D institute (section 6.3.2), although it might have a long way to go. Compared to Shanghai Bell, this learning process taking place in state-owned firms like LTEF was far more difficult. However, it was market forces underpinned by the emergence of economic necessities which made them want to learn (it could be said forced them to learn), and this even involved a risk that state-owned firms might get bankrupted before having accumulated basic capabilities needed to survive.

Alongside the contributions of market mechanisms to national systems of innovation, the state played an important role as a generator of incentives for technological development, which we address below.

8.3 State versus Market

There has been a long-standing controversy about the roles of state intervention versus market forces, as reviewed in chapter 2. This section explores these issues in the specific case of public digital switching technologies in China's transition in which market elements were introduced within what was at the outset a highly centrally controlled system, and the transition to a more market oriented economy within the framework of "Chinese socialism". It analyses the role which the state and the market played in PDSS technology development during such a period of transition, concerning their positive or negative consequences to PDSS technological development, to the technological dynamism of the country, as well as to the society. On this basis, it explores their complementary roles to each other.

Section 8.3.1 discusses the negative consequences of the market forces presented in the empirical cases, e.g. keeping technology secret from others, blocking the technological information flow, damaging technological co-operation amongst various players nation wide. Therefore, section 8.3.2 addresses the complementary role of the state to the market on the basis of the empirical evidence in the two PDSS cases.

8.3.1 Market Forces - Two-Edged Sword

As well as the positive effects of market forces on the innovation systems and the economic system more generally that were noted in section 8.2, the case studies showed that market forces can produce negative consequences not only for social and economic development but also for the technological development of the society.

Profit is an essential element of the market mechanism. In the case of HJD-04, the incentives generated by market mechanisms induced technological secrecy and protection amongst the three original developers and with the HJD-04 producers in different sectors of the country. When HJD-04 technology development entered the stage of marketing, and immediate expectations of profit come to the fore, friction between the three developers took place, as each party had its own vested interests and sought to pursue its own hopes to maximise income. Their behaviour in pursuing profit from the technology greatly threatened the technological collaboration between them. It blocked the flow of technological information needed between designers, producers and users for further technology improvement and innovation. Conflicts about which producers should be able to exploit the HJD-04 market also slowed the pace of HJD-04 production expansion, at the level of individual firms and nation-wide. This had strategic importance for the Chinese PDSS development as a whole. HJD-04 was still embryonic and it needed to compete in the Chinese market with foreign PDSSs, like System 12, which already had over half the market share in China. If HJD-04 could not expand its production capacity quickly enough, its small market niche might not be able to sustain the technology improvement needed at present and lay the base for future innovation.

Market forces drive individuals to pursue and maximise their own interests. Highly competitive market might also induce firms to pursue short term profit, which could deviate away investment needed for longer term technological development. We have seen in the empirical cases the clear difference between firms' interests and the interest of sectors and the state in technological development. For example, firms like Shanghai Bell had no interests in domestication of component production until importing large quantity of components became inconvenient for its production. It was also not keen to establish an R&D facility able to get involved in the core of the System 12 technology, because this would not bring the company any immediate benefit. It was the state which was interested in using System 12 as an advanced technological resource in order to bring the country to a higher technological level. Similarly, firms like LTEF had no interest in getting more switch producers involved in HJD-04 production. PTIC was only concerned to take care of firms in its own sector and tried to fend off all non-MPT producers. Concerning production expansion and further technology development, it was in the state's interest to promote wider technological co-operation across the country, e.g. between MPT and MMEI, in the further development of HJD-04, as MMEI was responsible for the electronics industry. For example, this might be important for the future supply of components for HJD-04 or its successors, if one day it is decided to shift toward domestic manufacture, e.g. of microprocessors.

We can see that market forces are two-egged sword which can produce both positive and negative outcomes for social, economic and technological development. The key question is the broader social and political frameworks which the market mechanism is embedded. For example, the HJD-04 case demonstrated that the incentives could lead to adoption of corrupt measures by firms (section 6.4.3). Given the newly established yet incompletely developed legislative system, plus the lack of legal tradition in China, and weaknesses in the internal administration and culture of firms, companies tended to make deals in a "simple" way, by providing rewards to the person who was in charge of the business. In these circumstances, economic incentives could damage the social order rather than bear a positive result for technology development.

Most common was the negative social consequences of the market competition, such as mass unemployment, a widening gap between the rich and the poor, etc., which could lead to social instability and unrest, and perhaps ultimately threat the survival of the whole system. As we have seen in the Chinese case, the immense surplus of workforce after the economic reforms became one of the major burdens of state-owned firms, seeking to be competitive in a more market-oriented system. Under the increasing pressure, the laying off spare workforce by state-owned firms seemed to be inevitable. As under the old Chinese socialist system, work units took full responsibility for social welfare, loosing one's job would be equal to loosing everything - being left with no social security, no health care, and no means of living. The market mechanism itself clearly has no facilities to look after its victims. If the market mechanism had been allowed to operate without limits in China, millions of people would have been immediately redundant, and social stability would have been at stake.

8.3.2 Complementary Role of the State to the Market

The empirical evidences presented above confirms the point noted in chapter 2 that market mechanisms can fail and must be complemented by public controls. In practice, there is no unregulated market in the world. Market mechanisms always work within a broader social and political framework, e.g. the legislative system, cultural system, etc. of a nation. State intervention is therefore necessary to offset the inadequacies of the market mechanism and reduce some of the negative consequences produced by it.

Apart from these general considerations, in the case of China, the introduction of the market mechanism began within the framework of the Chinese socialist culture and a centrally controlled system. As a result, the state's role was particularly crucial in designing the whole process of the social and economic transition, in initiating and directing the process, and waning away gradually the state's direct administrative control over economic affairs, while concentrating on the roles necessary and complementary to the market for national development as a whole. It had to find more effective forms of state interventions.

The two cases show that government intervention brought about a range of positive outcomes. First, the government policies set up the framework for Chinese PDSS technological development through technology transfer from abroad. The state directly intervened in the selection of technology and negotiation of the deal of PDSS technology transfer to ensure the independent productive competencies of the country in the PDSS and component technologies and to pursue the ultimate mastery of foreign advanced technologies. In particular, telecommunication is a public good and the backbone supporting the social and economic development of a country, and since PDSS lies at the heart of the telecommunications network, it always requires government attention to protect strategies for economic and public interests across the country, the balance between different regions through systematic planning and regulation. For example, using too many different PDSS systems could result unnecessary large costs and complex of maintenance, because of their interfacing and different maintenance skills.

Second, the state involvement in the dealing with foreign companies and governments lifted the business deal to a level of state affairs which ensured the reliability of the business deal, and overcame the weaknesses of Chinese individual companies with little experiences in foreign trade. For instance, the enormous size of China's telecommunications market was extremely tempting for all large PDSS producers in the world. This placed the Chinese side in a powerful bargaining position and eventually gained a fair deal and got the sanction lifted, which was posed by COCOM against high technology transfer to China.

Third, the state intervention successfully gathered adequate financial, material and human resources across the country in the support of the wholesale of System 12 technology transfer project. Like most developing countries, China's technological competencies in general are weak. However, if we compare technological competencies at the national level and the firm level, the former is much stronger than the latter. This is also the case in terms of the firm's financial, material and human resources. Only the state was able to overcome these weaknesses. The state intervention noted above provided a powerful momentum for initiating modernisation of the Chinese telecommunications infrastructure, which was definitely necessary at the outset of economic reforms and in dealing with a technology as complex as PDSS. In the case of System 12, the state's role was so crucial that without it the whole project would not have been possible or successful, in the circumstances that China lacked PDSS technological capabilities and the national system lacked dynamism for technological development.

Fourth, and more significant, the economic reforms led by the government created a new national system of innovation, which is fundamental for the country's technological development in the longer term. We have seen that during the course of the System 12 project, there was a progressive shift in state policy towards a more market oriented economic system through a gradual introduction of market elements, accompanied by loosening and decentralising state administrative control over economic affairs, that transformed the entire system towards technological dynamism. This new environment contributed greatly to the building up of the socio-technical constituency of the Chinese HJD-04 technology, and to the late achievements of this technology in production, marketing and further technological improvement, - even though the case of HJD-04 technology development did not directly involve government intervention as the System 12 case did.

Finally, the state made considerable effort in facilitating and promoting technological development at the national level. For example, it pursued the domestication of System 12 component production; the rapid expansion of System 12 production; the integration of System 12 technical upgrading with the new regulations and demands for the Chinese telecommunications infrastructure; the spin-off of foreign advanced technologies from Shanghai Bell to local industries; etc. All these confirm that the state role is needed, especially for the longer term development of the country. However, not all of these efforts were successful, as state intervention proved to have negative consequences too. The System 12 case showed that state intervention could result in inefficiency of allocating resources. The government policy of pursuing import substitution was not very successful at first in the case of the domestication of System 12 component production, and the financial investment of the government and effort dedicated into this project did not bear expected results. The main question may well be the implementation of the state intervention, rather than the role of the state in concerning the whole country, which we will discuss in next section .

8.4 Policy Implications

The previous sections (8.2 and 8.3) have already made a number of observations about the role of state intervention in PDSS technology development in China. It is important, at this point to have a further discussion of two related questions. In the light of the case studies, it needs first to note the changes in state intervention over time during the social and economic transition, and second to identify the different forms of intervention adopted and their different consequences, positive or negative. In this way, this section seeks to spell out the implications of the Chinese empirical cases, for the policies of the Chinese government for technology development and for transforming the national system of innovation in relation to future PDSS technological development.

This section starts by identifying the diverse forms of state intervention presented in the two PDSS cases and explores how they changed over time during the period of social and economic transition in China (8.4.1). It stresses that the state is not homogeneous, and different ways of implementation can produce different outcomes. It then discusses major government policies relating to PDSS technological development in the past and to technological dynamism of the country and their implications for future PDSS technological development (8.4.2).

8.4 1 Changing Forms of State Intervention

The form of state intervention has changed since the beginning of the transition. When the System 12 project was initiated, state intervention was still so direct that the state was the sole project designer, organiser, conductor and manager. Through an array of policies - including the wholesale System 12 technology transfer; component import licences (and the quota allocated for low tariff imports) and compulsory objectives for domestication of component production; the measures to restrict the number of kinds of foreign PDSSs in the Chinese telecommunications networks; and initiations for technology spin-off to local industries - we can see that the System 12 project embodied almost every element of government strategy for technology development of the country, relating to its three-step technology development policy.

With the deepening of the economic reforms, government control over firms like Shanghai Bell and LTEF became more indirect. Except for the particular link with MPT and the Shanghai municipal government, Shanghai Bell mainly benefited from being a joint venture and the "source of foreign advanced technologies" in particular. It enjoyed the general support from government policies: the low rate in taxation, more autonomy in business management, direct trading with foreign companies, more flexibility in currency exchanges, etc. In the domestication of System 12 component production, apart from the fact that the government still kept the control of component import tariffs, the direct intervention was largely reduced. It would seem that, as firms became more independent from the state and tended to pursue their own objectives and survive the market, direct government intervention became difficult and less appropriate.

In the HJD-04 technology development, the government did not give any direct support until the technology design had been proved successful. But this project was indirectly stimulated and initiated by a series of government economic measures and the general policies of the government for national technology development. HJD-04 represented a very different model than the conventional top-down approach, exemplified by System 12, in which the government directly decided the objective of technology development, laid out a large investment, and appointed technology developers. Instead, the idea of developing a Chinese PDSS was brought by a technologist. His personal attributes, which were crucial for HJD-04's success - his creative personality, entrepreneurial gifts and required technology expertise - would have mattered little, had it not also been that the Communist Party called for the shift of the central focus of military R&D and the market gave out strong signals indicating the enormous and increasing demand for PDSS technologies. Moreover, the government dual development policy made foreign PDSSs available in the Chinese market (including the System 12 technology transfer), which allowed PDSS technological information flow through both formal and informal channels to diffuse within the country. Similarly, the eventual construction of the HJD-04 sociotechnical constituency can be more or less implicitly and explicitly linked to the government policies to introduce market mechanisms and pursue dynamism in the whole national systems. The state budget and schemes for supporting new technology production were not attributed according to prior centralised plans, rather they were granted to projects like HJD-04 after the technology proved to be successful.

We have discussed in chapter 2 the negative consequences of the centrally controlled system, that the system itself was so rigid that it could not handle effectively the information flow between the R&D sector, industries and users and the complex mechanism of interacting between them. Take the project of the domestication of System 12 component production as an example. For each sub-project, many factors had to be considered by the organiser, the Shanghai municipal government. These included not only the problems of technology, the finance for each sub-project, but also the attitudes of Shanghai Bell and local producers, and the changing trends of technological development. Moreover, when the major players were not fully committed to the domestication, much important information could simply be withheld by them. These problems might in principle be overcome through more careful planning and closer monitoring of the process of projects by the government. However, it would simply have been too demanding for the government to deal with every single project in this detailed way. The state ability to become directly involved in such economic planning, particularly in a context of technological dynamism, is constrained both by its lack of access to the requisite technological information and its limited decision making capacity.

In addition, as already noted, state intervention is not homogenous. The state itself is fragmented, and its different parts tend to have sectional perspectives depending on their responsibilities, traditions, external constituencies and knowledge base. For example, MPT was the main state body involved in conducting the System 12 project. However, it was concerned with the telecommunications sector. It gave as much support as it could to Shanghai Bell to make the project work. When conflicts arose between PTIC and MMEI, MPT took the side of PTIC, trying to keep the HJD-04 exchanges that were being produced by MMEI's firms out of the public telecommunications network. On the other hand, MPT was not really involved in the domestication of System 12 component production, although it is also in the interests of the state. In contrast, MMEI and the Shanghai Municipal Government both actively pursued the domestication project. Differences emerged between them. MMEI wanted Shanghai Bell to take its own firms as component suppliers, while the Shanghai government preferred for Shanghai Bell to resort to local Shanghai industries and bring them up to the required level of technological capabilities.

The above analysis may suggest three points in relation to technology development in China. First, the government role in the technological development in particular a complex technology like PDSS seems to be evolving from direct intervention towards more indirect actions, seeking for example not to direct facilitating technological change, but to facilitate change and promote technological activities in a direction that would seek most of benefit for the entire country in the long term. This represented a gradual transition from the previously top-down process.

Second, some direct intervention may still be needed, as the state is the body responsible for taking a general longer term view - for example the requirements for national technological development. Since developing countries like China are constrained by a lack of resources especially in relation to technology, human resources and finance, nation-wide co-operation through the government intervention could be effective in creating and pulling together scarce resources. This is not to suggest a particular model for state intervention. The form of government intervention can be extremely diverse - ranging from direct control over individual projects, as the state did in the case of System 12, to facilitating and promoting technological changes, as the role the state played in creating economic incentives for technological dynamics, which indirectly helped the emergence of the HJD-04 project. Our considerations suggest that direct intervention may be most of risk of giving rise to negative side-effects or inefficiencies given the complex social elements involving in technological development processes. Thus direct state intervention needs to be carefully planned and implemented.

This brings us to a third and final conclusion - that state intervention is not homogenous, and that different ways of implementing state policies may well bear different results.

8.4.2 Policy Implications for China's Future PDSS Technology Development

Government policies in two areas need to be reviewed here: one is the policies having impact on PDSS technological development, the other is the policies which created new national systems of innovation. The former encompasses dual technology development policy, three step development strategy, import substitution policy in accompany with import licensing and tariff control, etc. The latter consisted of a series of policies being introduced in the course of socio-economic transition over time.

The government's dual technology development policy - of so-called "walking on two legs" - combining foreign and national aspects in the technology development seemed to have been extremely effective in PDSS technology development during China's socio-economic transition. Within this policy, the specific three-step technology development strategy identified by the Chinese government - involving respectively bringing in foreign product; technology transfer, and then indigenous development - has been successfully pursued in the PDSS technology field, and has yielded fruit. The import of foreign finished PDSS helped, especially in the beginning of economic reforms to solve the urgent problems, in the face of the lack of indigenous technology capability, to meet acute domestic demands for PDSS technology and contribute to rapid renewal of the Chinese telecommunications infrastructure. This also provided some information about advanced technologies and in particular allowed the society to develop new requirements and criteria for PDSS technologies. At the same time, government policies to deepen the economic reform, such as progressively introducing market mechanisms, loosening state control over economic activities, facilitated this process.

Wholesale technology transfer into China of telecommunications switching technology, the second step, began early, around the same time as the first purchase of foreign advanced PDSS exchanges, with clear the intention of building up Chinese PDSS production capacities and to meet the foreseeable increasing domestic PDSS demand. Local PDSS production capacities has contributed greatly to the modernisation of the Chinese telecommunications infrastructure and curbed the increasing import of finished PDSS exchanges. More importantly, the first two steps effectively enabled a wide range of people from designers, producers to users to get involved in technological learning and to accumulate technological capabilities - as indicated in chapter 7.

Indigenous technological development as the third step, including adapting foreign advanced technologies, spinning off advanced technologies to other local industries, and even developing Chinese PDSS technology, has therefore notably benefited from the previous technological activities. Without them, the Chinese HJD-04 technology development might not have been able to selectively utilise the international technology market and embark directly on designing a Chinese digital programme-controlled switching technology without repeating protracted development stages which preceded them in the industrialised world.

The coexistence of Chinese and foreign PDSS technology in the Chinese telecommunications market not only helped to meet diverse requirements of domestic customers for PDSS technologies, but also propelled both technologies towards further technology improvement and innovation toward high quality products and service as well as low prices.

Ironically, the HJD-04 development did not get much attention and support from the government, especially in the initial stage of technology creation. MPT even tried to stop the process, regarding this project as an unnecessary "duplication" and competition to its own candidate for an indigenous PDSS. This attitude did not change until the HJD-04 technology proved to be successful. At a later stage, the dispute between MPT and MMEI did not help to unite HJD-04 production capacities cross their respective industrial sectors. Rather it ruled out the cross sector technological co-operation which could have enabled rapid expansion of HJD-04 production.

HJD-04 technology was still embryonic. The state-owned companies that produce it faced constant problems and pressures from the broad economic transition. Compared to privileged joint ventures like Shanghai Bell, state-owned firms like LTEF arguably needed more government attention. For example, HJD-04 producers might need the government to grant them direct access to the international electronics market and autonomy to arrange adequate foreign currency for purchasing HJD-04 components. As we have noted, state-owned firms like LTEF faced not only the problems of resource shortage, but also the inherited social and economic burdens. In addition, because the market mechanism does not automatically give priority to indigenous technologies like HJD-04, intervention by central government is needed to encourage indigenous technological development.

Contrasting MPT's attitudes toward HJD-04 and System 12, so far, it seemed that MPT has been more concerned with the rapid expansion of local production of foreign PDSSs like System 12 to modernise public telecommunications network and meet urgent domestic demands than the Chinese HJD-04 PDSS technology development which might bring about benefit in the longer term. Indeed, it is often difficult for MPT to balance the short term and longer objectives of the PDSS technological development to the country, given the growing domestic PDSS market.

The government's early attempt in restricting the number of different types of foreign PDSSs did not sustain, because the later decision of the government under the pressure from Western governments and US in particular to open even wider the Chinese telecommunications market to the world (section 4.3). This does not mean that the government earlier effort was wrong. Rather, it demonstrates the important role of the central government in dealing with foreign trade to balance different interests of the country.

In relation to government effort in import substitution, the frustrating experience does not necessarily suggest that the policy was wrong as addressed above. It at least helped local industries to understand the essential elements of production linking to the world standards and compelled individual firms to accumulate the basic technological capabilities needed to survive in a more market-oriented environment. The forms of state interventions and the ways of implementing the state policy need to be carefully considered, as discussed early.

8.5 Concluding Points

The two Chinese case studies showed that firms lacked even the most basic technological capabilities, such as production quality control, marketing, resource allocation and management. These problems are deeply rooted in the old institutional framework of Chinese state socialism. Technological development is a complex social process which involves a much wider range of different groups and organisations than was presumed in traditional models of socialist planning. In chapter 7, it was already noted that mass involvement in technological learning is crucial for improving technological capabilities of a firm and a nation. Technological learning is not only associated with those directly involved in the processes of technology creation and design, but also producers and users. Indirectly, the circle of relevant actors may well be much larger, involving perhaps financiers, educators, students, local and central policy makers, etc. To enable the effective exchanges of technological information between institutions and individuals in the society requires an supportive institutional framework and incentives for technological changes. In this respect the old centrally planned system in China certainly could not provide such a national system of innovation.

China's social and economic transition has introduced market elements into the system. State administrative control over economic affairs has been gradually replaced by market forces. With respect of the Chinese PDSS cases, we have seen that the transition brought about at least three major important changes:

a) new types of technological collaboration have emerged between R&D institutes and manufacturing firms;
b) the attitudes of people and organisations, including R&D institutes, manufacturing firms and others, towards technology have changed, and these bodies become more involved in technological activities; and
c) technological learning has been encouraged and has involved more people and a wider range of organisations in society, which has helped the accumulation of technological capabilities at both firm and national levels.

As noted in chapter 7, firms have been motivated to seek technological opportunities and to build up technological capabilities. In particular, there have been rapid improvement in basic technological capabilities at firm level, e.g. production, marketing, resource allocation and management.

As the transition started from a highly centrally controlled system, the newly introduced market mechanism has actually been working alongside the existing yet reducing state powers. This study has shown that government interventions relating to PDSS technological development have, so far, brought about a range of positive outcomes. Without these state actions, neither the System 12 nor the HJD-04 project would have not been possible and successful. In relation to the national systems of innovation, the state played major role in transforming the old rigid system into one with more technological dynamism. Apart from that, state intervention in PDSS technological development provided a powerful impetus to the modernisation of the Chinese telecommunications infrastructure. The Chinese PDSS cases show that the state and market forces can both generate incentives for technological development. Moreover, because China's transition is more or less top-down process directed by the government, the state as its designer, conductor, monitor and executive, is therefore particularly crucial.

The Chinese PDSS case study shows that market forces can produce negative consequences not only for social development but also technological development. This was very much so in China's transition, in which old structures and traditions inherited from the exist alongside the newly established systems, e.g. the legislative system, government regulations relevant to the market operation, etc., which are still incomplete, or have not been fully established within the whole society. The newly introduced market mechanisms are still far from mature.

Therefore, state intervention is necessary to compensate the inadequacy of the market mechanism, to confront negative consequences and to balance the interests of individuals, institutions and the nation as a whole. Moreover, the state needs to continually adjust its role in accordance with the increasing role of market forces during the period of transition. Some functions carried out by the state can be effectively replaced by the market, whereas others are always needed and may need to be strengthened.

Concerning the particular development of PDSS technology in China, state intervention is needed at least for several reasons. First, the state role is necessary for setting up the longer term development strategies and frameworks, e.g. through wholesale technology transfer from abroad to build up indigenous technological competencies. In particular, PDSS technology lies at the heart of the telecommunications network which is very crucial for the social and economic development of a country. Second, as PDSS is such an advanced complex technology, its development and technology transfer from abroad need large investments of financial, material and human resources. Thus, government effort may well be needed to gather strong resources nation-wide and effectively utilise them to ensure the success of technological development. Third, China as a highly populated country with a potentially huge PDSS market, it is an extremely attempting market for all large PDSS producers in the world. The country as a whole has a very powerful bargaining position to deal with foreign companies and governments. This was particularly important at the beginning of economic reforms when China had been isolated from international business society for thirty years, individual companies lacked capabilities and experience in foreign trade and certainly were not able to handle a technology transfer project like System 12. Even if they could, foreign companies like BTM and the Belgian government might not be sufficiently confident to commit such a large investment in China without Chinese government involvement.

Certainly, state intervention can produce negative consequences. As the Chinese case study shows technological development involves many elements - social, economic and political as well as technical. Many of these elements may be counterposed. In addition, there is enormous uncertainty emerging in the process. Thus state direct involvement often results in some negative side-effects, because it is always difficult for state to manage such complicated and often contradictory technological development processes. One aspect is that the information needed to manage this process may often be in the hand of private actors and be withheld for their own particular interests. Apart from that, this research has shown that major problems surround the form of intervention, that is, the manner in which state intervention is carried out. State intervention is not homogenous, and different bodies of the state, while developing and implementing state policy, might well conflate their local interests with the interest of the whole state or indeed nation.

The Chinese case also shows that the forms of state intervention have changed over time during the transition period. With respect to PDSS technology development, extensive government direct control, instruction, management and financial and material support in the beginning of the economic reforms has been reduced over the period of time. State intervention has become more indirect, through establishing a legislative system and issuing regulations, through restructuring institutional frameworks, measures and by setting up supportive schemes. Many of these are generalised in their approach, procedures and effects rather than being concerned with specific matters.

On the basis of above points, we may suggest that: i) there is a need to explore diverse forms of state intervention, which can range from direct controlling individual project to facilitating and promoting regulations and measures; ii) direct state intervention to achieve particular social and economic goals may possibly bring about unintended negative side-effects, because of the difficulties inherent in managing a complex technological, social, economic and political situation; iii) there is a need to identify different forms of intervention and selecting appropriate way of implementing policy and suitable state body to carry this out; iv) indirect measures - e.g. through using markets to motivate technological dynamism as well as regulations and fiscal measures - are also needed.

We may also conclude that in general, the broad framework of government policies for technological development and restructuring national system of innovation, relevant to the Chinese PDSS technological development, are correct and necessary. The government's dual technology development policy - "walking on two legs" - and the three-stage technological development strategy have greatly contributed to the Chinese PDSS technological development. In the first stage, China imported foreign finished PDSS technologies which solved the urgent domestic demands, helped the construction of the Chinese telecommunications infrastructure and, moreover, provided a window for the Chinese to learn about advanced PDSS technologies. This helped the second stage - transferring complete PDSS technologies like System 12 into China. This step has successfully built up China's PDSS production capacities and has also greatly contributed to the modernisation of the Chinese telecommunications infrastructure, bringing about a leapfrog in switching technology in China, as noted in chapter 7. The first two stages provided technological resources for indigenous technological development and both direct and indirect means for technological learning. In a very real sense, without these, the Chinese HJD-04 technological development might not have been possible. Moreover, the coexistence of Chinese and foreign PDSS technologies as promoted by the government's dual technological development policy helped to meet the requirements of domestic customers and in particular compelled indigenous technology producers to improve the quality of production and services and further innovate, as already noted in chapter 7.

However, the Chinese PDSS technology is still embryonic, and the problems facing HJD-04 are enormous. To compete with foreign PDSS products, including those locally produced like System 12, rapid expansion of HJD-04 production capacity may well be needed, as well as further technological innovation. With increasing production, domestication of components production for HJD-04 may need to be considered. This suggests the need for a nation wide technological co-operation, (e.g. between MPT and MMEI), only the government can play the role in cordinating the matter. The Chinese PDSS case shows that there is a gap to be filled by the state.

The Chinese case proved that import licensing and tariff control as well as the domestication project directly organised by the government more or less helped to propel local industries into the technological learning processes. However it is equally clear that this policy made little headway in the early stages because of lacking impetus from local firms. Only later, when there was a broad coincidence between the self-interest of firms, did these policies prove fully effective. Clearly, the form of state intervention, and the circumstance of domestic component production needs to take into account.

Obviously, the restructuring national system of innovation is crucial for technological development, however it has still a long way to go for the Chinese government. Although some kinds of state intervention are always required to be complementary to the market mechanism, the form of intervention needs to evolve continuously to match changing circumstance, e.g. the maturing of market mechanisms. In the meantime, an appropriate social framework needs to be set up to work together with market forces in order to reduce the negative consequences on technological development as well as on broader society.

Chapter 9:

Conclusions and Wide Implications for Developing Countries

9.1 Introduction

The preceding two analytical chapters, 7 and 8, discussed issues thrown up by the two empirical studies and related them to the main research questions posed in chapter 2. This final chapter seeks to link the conclusions from the empirical research to the theoretical framework and concerns of this study. It further examines how relevant these findings are to the main policy issues and concerns of developing countries, especially for developing countries which have been socialist states. It also considers the extent to which these findings may be specific to China and/or the particular technology, PDSS. Finally it reflects upon the study undertaken to spell out some implications and opportunities for further research.

This chapter is arranged in seven sections. Section 9.2, "Development or Dependency", addresses the fundamental theoretical issues and policy concerns which emerged from the review of literature in this area which provides the starting point for the rest of the chapter. It reviews what China's experiences in PDSS technology development may contribute to these fundamental issues.

The next two sections focus on the area of technological development in developing countries. Section 9.3, "Technology Transfer and Indigenous Technological Capabilities", explores the possibilities for generalisation about the notions postulated in Chapter 2 concerning technology transfer, indigenous technological capabilities and technological learning as well as their close links. Section 9.4, "Local Shaping of Technology", relates the empirical findings to the perspective of local shaping of technology, to analyse the strategies available for developing countries to selectively utilise foreign technological competencies in order to meet local needs.

Section 9.5, "National System of Innovation" and section 9.6, "State Intervention versus Market Forces", address respectively how China's social and economic transition has contributed to technological dynamism with regard to the concept of national systems of innovation and the policy debate on the complementary role of the state to the market. As a summary of the concluding points as well as an evaluation of this study, section 9.7 brings forward possible contributions of this study to knowledge. The final section (9.8) proposes issues for future study.

9.2 Development or Dependency

This study has shown how, in PDSS technological development, China has successfully utilised advanced foreign technological competencies through technology transfer to fulfil its national objectives in both technology and economic development. In less than fifteen years, China managed to expand its telecommunications network capacity 21 million telephone lines. It also modernised its switching technologies and leapfrogged older vintages of technology (e.g. analogue automatic switches), by replacing other lower technology switches with digital programme-controlled switching systems. At the same time, China as a whole has built up PDSS technological capabilities not only in production, operation, maintenance, but also in innovation and creation of new technological knowledge.

This study shows that, given the right conditions, it is feasible for developing countries to catch up and overcome existing "gaps" between the developed and developing countries. Certainly, developing countries can benefit from advanced technologies developed in the West. Technology transfer is a means for developing countries to reap benefits from these technology without the need to recapitulate the technological development that led to their creation. Developing countries while transferring advanced foreign technologies may also be able to avoid some of the mistakes that the West and NICs may have made in the course of earlier technological development and/or technology transfer. However, technology transfer does not need to resemble the Western model of development in the structures and patterns proposed by modernisationists. Nor is technology transfer a simple linear process of transporting geographically a technology from one place to another - as criticised by dependency theories. As pointed out in section 2.4.2 and 2.4.3, technology transfer is a complex process of unpacking, mastering and assimilating imported technologies. Strictly speaking, in the process of technology transfer, the original technologies are altered. The success of technology transfer is bound up with the behaviours of both suppliers and recipients, which involves a significant degree of uncertainties. Whether the results of technology transfer favour recipients - the developing countries - depends greatly on how the processes are carried out. This raises important questions about how technology transfer projects are strategically planned.

Based on the evidence of the Chinese PDSS case, this study indicates that there is a need for effective strategies to use available domestic resources, as well as to identify and exploit opportunities emerging in the dynamic global economy, given that developing countries lack financial and technological resources. The latter point places developing countries in a rather a weak bargaining position in the international markets. In this respect, this study confirms that the structural approach (section 2.2.1) by dependency theorists is useful for developing countries to understand the potential pitfalls in development. However, it provides them with little practical advice about how to avoid these hazards and further to actively make use of the emerging opportunities.

It is a challenge for DCs to escape economic and technological dependencies. Since the problems which were pointed out by dependency theories still exist, this study suggests that they might be reduced, by means of, for example, selective use of foreign technological competencies and their combination with local competencies, through the local shaping of imported technologies. The empirical cases presented in this study provide clear examples of this. This has underpinned the conclusion in section 7.5 that the key questions for developing countries seeking to reduce dependencies concerns whether they can successfully build up technological capabilities through technological learning during the course of technology transfer.

This study suggests that the problems of dependency should not be reified or overstated. In a sense, dependency is always mutual between technology suppliers and recipients. For instance, in the Chinese case, China needed to gain access to foreign PDSS technologies, while foreign switching producers needed to gain access to the Chinese market. The question thus concerns the balance between them, and the extent to which China can maintain the key advantage or gain even stronger position. These considerations underpinned a number of important choices in the technology transfer of System 12 technology. If China could not produce the specialised components required - in particular custom LSI chips - for System 12, China would have to rely on foreign producers. If their production was monopolised, then the situation would have been less favourable for China. In this situation, China could have lost the balance of power and might have suffered from unfair treatment, such as e.g. high priced components, outdated technologies, etc. What actually transpired in this case was the opposite. China has gained a stronger position through technology transfer. More importantly, China has developed indigenous PDSS technologies like HJD-04 which have the potential, one day, to compete on equal terms with foreign products in the market. In these circumstances, China's dependence on foreign technology suppliers does not necessarily mean that China is in an unfavourable bargaining position.

This bears upon the controversies in development studies about whether the NICs' experiences are relevant to other developing countries. The Chinese case confirms that, although their circumstances may be rather different, some of the lessons drawn from the NICs' experiences are useful - for example, that NICs could not only acquire the capacity to produce Western technologies, but could also develop innovation competencies. The key question for developing countries thus becomes how to achieve technological dynamism (discussed further in section 9.5). It also shows that the state can play a complementary role to the market mechanisms in providing an environment for technological development (discussed further in section 9.6).

However, there may be limits in the extent to which one can generalise from the Chinese experiences in PDSS technology development for developing countries. First, China is a large country. In terms of its size alone, it has a special position in the world economy and politics. Its huge market makes it an extremely attractive element for many businesses across the world. For the same reason, it makes sense for Chinese to develop its own PDSS technology which can best suit the Chinese conditions and to compete with foreign products in sharing the huge domestic market. For small countries, it may not be economical to do so, since the development costs for PDSS technology are huge, and a small domestic market might not be able to sustain a domestic production capacity, let alone further innovation of the technology. Second, PDSS technology has particular social, economical and political significance, and is thus frequently subject to state intervention. Other technologies may well be different in terms of these requirements.

9.3 Technology Transfer and Indigenous Technological Capabilities

To a large extent, we can conclude that China's technology transfer from abroad has been effective in respect of the acquisition of technological capabilities. The wholesale of System 12 technology transfer provided avenues for technological information inflow and a wide range of means for technological learning. This also indirectly provided the basis for the Chinese HJD-04 technology to emerge, which was enabled by combining the selective purchase of foreign components (cheaper, standardised microprocessors and design tools) and locally available expertise in computer design, and the knowledge of the Chinese telecommunications system. Technological learning - by using, operating, producing, adapting, designing, creating, innovating, etc. with involvement of a wide range of people - greatly contributed to the accumulation of indigenous technological capabilities. The study highlights the importance of informal as well as formal links and knowledge flows for this.

Chapter 7, on the basis of the empirical cases, has discussed the close relationships between technology transfer, accumulation and indigenous technological capabilities and technological learning (7.5.). These findings verifies the presumption indicated in section 2.4.2 that technology transfer is necessary for developing countries to build up technological capabilities. The key for ultimately acquiring exogenous technological competencies which are embodied in the imported technologies are to select, unpack, adapt imported technology. Rather than counterpose technology transfer with the acquisition of indigenous technological capabilities, a close and well chosen relationship is needed between technology transfer and indigenous technological capabilities, especially in technologies like telecommunications which is globalised, complex, huge development costs, network technology. All these match my understanding drawn upon the literature review of the relationship between technology transfer, indigenous technological capabilities and technological learning (section 2.4.1 and 2.4.2.).

In respect of the concept of technological capabilities, distinctions have been drawn between the capabilities of production, operation, maintenance, resource allocation, marketing, management, etc. and the capabilities of indigenous innovation and creation - technological capabilities at basic and advanced levels (section 2.4.2). My initial presumption prioritised the (advanced) technological capabilities of innovation and creation, the same as much research which has regarded them as more important for developing countries to overcome dependency. After completing the discussion and analysis of the empirical material from the two Chinese PDSS cases (section 7.5), it seems to me that this presumption was perhaps misplaced. Instead, the cases demonstrate the pressing task of DCs in developing and strengthening basic (operational) technological capabilities. There are two reasons for this. First, basic (operational) technological capabilities create the basis for wider advances in economic growth and provide the foundation for the development of more advanced technological capabilities, for example through the effective use of foreign advanced technological competencies. The fact is that, in most developing countries like China, these capabilities in general are weak. And this is particularly true for former socialist states in which individual firms lacked these basic capabilities which were poorly developed as a result of the central planning system. Second, the development of basic (operational) technological capabilities requires mass involvement in technological learning, demanding also a supportive social and economic system, in contrast to the development of advanced capabilities in technology creation which focuses attention more narrowly, perhaps on the activities of a handful of (maybe extremely clever) engineers and/or technologists.

The findings of this study confirms that it is useful to distinguish the technological capabilities at the national level from those at firms' level (section 2.4.2). It shows that in a developing country like China, technological capability at the national level can be much stronger than that at the level of the firm, although its mobilisation depends on effective technological collaboration between organisations. For example, there are few Chinese individual firms have PDSS R&D capacity but, having co-operated with R&D institutes, they can develop and produce PDSSs like HJD-04. This highlights one of the major issues of this study, the role of institutional linkages and government policies in supporting technological co-operation and in fully utilising existing technological competencies across the country.

9.4 Local Shaping of Technology

This study challenges classical intermediate/appropriate technology theories, which suggested that advanced Western technologies embodied presumptions from their development context that made them inappropriate for developing countries - thereby foregoing the benefits that these powerful and efficient technologies might offer (section 2.4.3). It applies insights from the social shaping of technology approach to explore how developing countries can beneficially acquire advanced foreign technological competencies. It highlights the scope for developing countries to selectively utilise foreign technologies, and adapt them to local circumstances - and addresses the range of government policies and technology strategies that may be pursued.

The social shaping of technology approach draws attention to the *process* of innovation: to the choices inherent at every stage of technological change and the way these are affected by their socio-economic context as well as narrowly technical considerations; to the negotiability of technology and the way that artefacts once developed are not fixed after they leave the R&D laboratory, but may evolve and be further innovated as they enter commercial production and use. Applying this perspective to technology transfer highlights the possibility of the selective acquisition of technologies as well as choices about which elements of technology should be unpacked, adapted to local conditions or developed and produced locally. Therefore, there is in principle a range of strategies available for developing countries to adopt, accordant with their domestic requirements and their existing technological capabilities as well as external opportunities. The empirical cases demonstrate how different strategies have been successfully applied in Chinese PDSS technology. Chapter 7 has already analysed and compared in detail the two strategies presented by the case of System 12 and HJD-04, and discussed advantages and shortcomings of using them in different circumstances.

The SST approach is very useful here in distinguishing different types of technologies in terms of physical artefacts which may be developed in different ways and offer different scope for local shaping. In particular following Fleck (1988) (section 2.4.3) this study suggests that complex modern technologies are increasingly "configurational" (they may be acquired as technology assemblages of more less standardised component technologies configured together with customised elements) rather than as internally homogenous, monolithic "systems technology". Such configurational technologies can be reconfigured in their implementation and use. This study shows that even large scale proprietary technologies such as System 12 PDSS can be unpacked and further innovated. This suggests that the ideal type of "system technologies", against which concepts of configurational technology have been counterposed, may not in fact exist.

Finally, as concluded in section 7.5, the study suggests that the type of technology, and the type of technology transaction, together determine the availability and appropriability of exogenous technological competencies which are embodied in the imported technologies, and provide different means for technological learning.

9.5 National System of Innovation

The concept of national systems of innovation may be helpful for a country, especially a developing country, seeking to catch up with technologically advanced and dynamic economies. It draws attention to the socio-economic institutional framework for innovation and to the influence of government policies. It highlights the links between agents involved in technological activities and incentives for technological innovation.

From this perspective, we can see that China's social and economic transition, involving the introduction of market elements into the system to replace some state roles, has contributed to the technological dynamism of China's national innovation system. This has gradually overcome problems that had beset the socialist central planning system, and which arose in particular from the poor links between R&D institutes, producers and their customers. The study showed how, in this transition, the market forces and government policies combined to provide important incentives for these players to seek opportunities from new technologies, to get involved in technological learning, and to engage in collaboration to these ends.

However, to some extent, the concept of national system conveys an image of a process that is systematic, ordered and stable. The findings of this study point to the fragmented and chaotic nature of the social and economic system. The changing social and economic context in China's transition suggests that it is unhelpful to search for a single best model for a particular nation's system for innovation, as national systems need to evolve in order to be best suited to promote innovation in a changing commercial and technological world. Just as important, there may be no single best national system for a country as a whole, not just because of regional differences, but also because the features of different national systems of innovation for different industries and different technologies may well need to be different.

9.6 State Intervention versus Market Forces

One of the main area of debate among different schools of thought within development studies reviewed in chapter 2 concerns whether state intervention played a positive role in economic development in NICs (section 2.2.2). The empirical findings from this study show that state intervention can indeed play positive role; it can also fail. Chapter 8 analysed failures of some state interventions in the two PDSS cases. Two key elements have significant impacts on the outcomes of state intervention: the form of intervention and the state body which carries out the tasks (section 8.5). This study in particular stresses the need to explore diverse forms of state intervention which may need to be adopted to meet continually changing domestic and international environments. Also, it points out that state intervention is not homogenous, as the state itself is fragmented, and each body of state has its own vested interests and commitments which shape the ways it intervenes.

In relation to the debate about whether state intervention is necessary (section 2.2.2 and 2.3.3), this study rejects firmly the schools of thoughts which believe in *laissez-faire* approaches. The empirical findings from this study prove that although many state roles can be more effectively replaced by market forces (particularly to create technological dynamism in the system, in primarily generating incentives for individuals and organisations), some others are always needed, for example, to represent national interests. This study fully agrees with these studies on the NICs' experiences which emphasise the government roles in provision of appropriate macroeconomic policies and infrastructure; in issuing restrictions on imports for industrial promotion, etc.; in formulation of the long term national plans for investment and industrial development whereby to guide the market; and in control of the content and pace of industrialisation (section 2.2.2). In its roles in guiding capital investment and technological development, the state is able to provide strategic direction which could not be guaranteed by the market-oriented behaviour of individual firms. An important aspect of this intervention is that it complements rather than displaces competition and the market system.

Chapter 8 also analysed some of the negative consequences of introducing market mechanism in China's economic transition and the different reactions of agents involved in technological activities to market forces in different circumstances arose in the two PDSS cases (section 8.3.1). This shows that market forces represent a two-edged sword. The analysis further confirms that market mechanism always works within a broader social and political framework, for example, markets are always subject to some form of regulations (section 2.3.3). Markets in the real world are far-removed from ideal descriptions of the free market. As noted above in section 9.2, this study goes further to argue that state intervention is needed to compensate for some of the failures of the market mechanism, in particular to take responsibility for reducing some of the negative social consequences that may be produced by market forces. Relating this to the debates about socialist economics, it suggests that the "simple dichotomy" between socialist and capitalist systems has little use for developing countries. In practice, governments always face a challenge to reduce potential areas of "market failure", to balance public interests and economic efficiency, and to combat, or at least ameliorate, negative social consequences which could lead social instability and could well jeopardise the development process of a country altogether.

9.7 Summary - the Contributions of this Study

In summary, the claims of this study to contribute to knowledge rest upon its empirical strengths and significance, and on its success in integrating perspectives from three broad fields: development studies; the study of socialist economies and technology studies. The latter, and in particular the social shaping of technology perspective, has opened up for enquiry the content of artefacts and innovation processes and has, in turn, drawn attention to the range of ways by which developing countries may utilise advanced western technologies in acquiring technological competencies.

This study has presented a very detailed account of the development of PDSS in China. This is *per se* a significant area, as PDSS is a complex, large-scale technology with strategic economic and social importance. There have been some other studies of the development of telecommunications in China and other DCs and other technological developments in China. However these accounts have often been of a generalised nature, and overly dependent on national statistics and central policies. What makes this study special is its highly detailed empirical analysis. This encompassed the roles of the key constituencies involved in technology development and the broader context. The cases document the changing behaviours of the actors involved, and link these to the broad social and economic context which was changing rapidly as a result of China's economic transition. Their roles have been explicated through a comparative study of two significant but contrasting cases which highlight two different strategies for utilising advanced foreign technologies.

This study applies perspectives and approaches from three disciplines: development studies, the study of socialist economies and technology studies. In this way it contributes towards a better understanding of the problems (and opportunities) of developing countries - and in particular former socialist states - in technological development. The social shaping of technology perspective suggests a need to shift from the generic accounts of underdevelopment that have prevailed in development studies and instead to open up the processes of innovation for detailed examination. This enables a focus on the strategies whereby developing countries might benefit from modern technologies developed elsewhere. Like the earlier experiences of the NICs, this study suggests, on the basis of the empirical analysis of the Chinese PDSS cases that developing countries are able to utilise foreign advanced technologies successfully. It further points to the range of different strategies that may be available for acquiring technological capabilities through technology transfer and technological learning.

In particular, applying an SST perspective, which opens up the composition of technology for analysis, reveals that an advanced technology like PDSS is not unitary, despite perceptions that it comes as a finished system. Instead technologies increasingly take the form of complex assemblages of component and custom elements. While it is possible to acquire foreign advanced technologies as finished final solutions, as in the case of System 12, components and tools for building such technologies can also be bought in. Such an insight calls into questioning the presumptions of intermediate technology which see Western technologies as building in sets of presumptions and values from the societies in which they were developed which will remain inappropriate for the capabilities and cultures of developing countries. Instead it shows that developing countries can resort to technologies on a selective basis and further that there is scope to unpack technologies and locally shape and reshape them. In particular, it demonstrates that developing countries can also master advanced technologies by combining internal and external technological competencies. Indeed this is likely to become an increasingly common feature. Under the world trend of globalisation, self sufficiency of a country in the area of advanced technologies is becoming less important - even developed countries may not be feasible to maintain the full range of capabilities in a technology (as is already the case in relation to micro-electronics and computing, except for a handful of the most developed countries). Developing countries and even small countries, may be able to acquire partial competencies in advanced technological fields.

This study sees technology transfer as not a narrowly technical issue, but also as a profoundly social, economic and political one, linked not only to the domestic system, e.g. institutional structure and government policies, but also the world technology, economy and politics. The study shifts the focus from the static model of dependency that has underpinned structuralist and dependency theories in development studies to a dynamic one presenting developing countries with a number of options. It flags the balance that exists between suppliers and recipients (at firm and at national levels) and sees technology development as a strategic issue for developing countries in choosing how to deal with a changing world, as well as an issue of how recipients to strengthen their position by building up technological capabilities while suppliers are seeking to maximise and sustain their position in the global market.

This study finds value in the concept of national system for innovation in drawing attention to the crucial role of the broad social and economic context of technological development in a country. On the other hand, it suggests that the concept of national systems of innovation may prove unhelpful if they land to a static and undynamic search for a single fixed best model.

Drawing on diverse theoretical roots the study highlights some of the features underpinning the lack of technological dynamism in China's former socialist system. It broadly confirms findings from studies of other socialist economies that the major obstacles for technological development in China have been the weak operational technological capabilities of individual firms, and those weaknesses are associated with the socialist central planning system - the lack of linkages (and lack of incentives for such links) between R&D and manufacturing organisations and with their customers.

The empirical cases of this study adds rich materials to the understanding of the close relationship between technology transfer, technological learning and accumulation of indigenous technological capabilities. These are integrated into the discussion of a range of technology strategies available to developing countries and in particular the scope to selectively utilise exogenous technological competencies to meet their optimal interests.

Much research has more or less explicitly prioritised the development of indigenous technology creation capabilities (i.e. the capacity to create novel technologies), seeing them as more advanced, and necessary to truly overcome dependency. (This was also a personal presumption at the outset of the study, as stated in chapter 2). However, one of the key findings is that the firm's acquisition of basic (operational) capabilities is perhaps the most pressing task. They are of most immediate importance in allowing a developing country to benefit from advanced technologies; they strengthen the local economy, and also provide the basis for further technological development, including technological innovation, in both the firms which have received technology transfer and their local suppliers. The development of basic (operational) capabilities requires not just capital equipment and engineering knowledge, but also broader changes in the social and economic system. For example a key feature was recognition of the importance of quality and meeting customer requirements. Such developments called for mass involvement in technological learning. Given that innovation is not a linear process, limited to initial R&D, the boundaries between technology production and creation capabilities may not be clear cut - given the need to adapt technologies to local socio-economic and technical contexts. Moreover, these may provide the basis through technological learning for developing advanced indigenous technological capabilities, including, as the HJD-04 case shows, technology creation capabilities.

This study shows how the increasing influence of market forces contributed to technological dynamism in China. However it does not favour a *laissez-faire* approach. Instead it supports the view that the role of market and state are complementary rather than being counterposed, and in particular provides evidence that state intervention plays a number of important roles in technological development - in supporting the development of technological capabilities as well as its role in pursuing broader and longer term interests. These issues arise in a number of social formations, as well as just the case of China, suggesting that the traditional dichotomy between "socialist" and "capitalist" countries may no longer be helpful.

9.8 Future Research

Inevitably when any research project is completed, opportunities remain to extend the scope of investigation. In particular it proved necessary in this work to select two cases for detailed study - Systems 12 and HJD-04. There was also a Chinese developed PDSS, the DS-series (discussed in chapter 3) - although this was a more conventionally planned project than the HJD-04 case which perhaps offered fewer insights. It was also less successful in many respects than HJD-04. However a study of the development processes with the DS-series, in comparison with HJD-04, would help to understand the more traditional model of technology development in China, and might draw attention, for example, to the importance of the market in stimulating close links between technology designers, producers and users, and how this shaped the parameters of technological development process as well as artefacts.

In addition, follow-up research will be valuable on the two case-studies undertaken, for a number of reasons. First, at the time of completion of fieldwork, the commercial prospects for HJD-04 were far from certain. Subsequently it has been widely adopted - having exceeded ten million lines in 1997 (China Daily, 28.8.1997). System 12 also seems well entrenched commercially. As the market competition intensifies and shifts from favouring supplier to customers, with the gradual maturation of the market - particularly with the entry of the new player, National United Communications Corporation (UNICOM)[1], into the telecommunications services market to challenge MPT's monopoly (The Economist Intelligence Unit, 1995) - questions arise about how Chinese HJD-04 systems (or for that matter DS or Systems 12) has been able to sustain and improve its position in the market. If they succeed as said in "A Postscript", it will also be interesting to see whether they can enter the international PDSS market.

Second, questions arise about how the technologies of System 12 and HJD-04 will innovate to meet continually changing demands of the Chinese market, and global changes in telecommunications technologies. In relation to System 12, these may well bear upon the relationship between Shanghai Bell and its parent company, and whether it will be allowed to expand the realms of its technology innovation capacity. In relation to HJD-04, it remains to be seen whether or how the rather disorganised, and extremely "lean" collaboration, that sustained the original development of HJD-04, has been changed to support its further innovation.

Finally, follow up research could throw more light on the unfolding of China's innovation system, as economic reforms gather pace - addressing, for example the

[1] It was established in 14 July 1994 by ministries of Electronics Industry, Power and Railway.

increasingly competitive nature of markets and the emergence of a legal and policy framework to support these.

Another set of questions, and further research opportunities arise about the scope for generalising these findings. First concerns their applicability to other countries. Here it might be interesting to compare the Chinese experience with the historical experiences of the NICs to flag the role of their particular national contexts and the broader global setting (for example when following the end of the cold-war, globalisation has become the dominant trend). The latter suggests that development strategies must be set against the evolving global technology context. The question becomes how nations can develop policies and strategies to exploit emerging opportunities in the world technology markets and strengthen their bargaining position.

There are further opportunities for comparison with other developing countries and other transitional DCs like Vietnam in particular. There are important differences between China and other DCs. It will therefore be interesting to conduct international comparative research into PDSS development in other DCs (for example, to compare socialist and non socialist states, large and small countries, etc.). There is a continuing need for further systematic research for developing countries into the range of technology transfer strategies, categorising their respective advantages and shortcomings. Another dimension would be to examine other technologies which might have different technical and market features (for example PDSS is very much a centralised, large scale technology, subject to considerable direct state intervention in both its development and use; rather different characteristics might be found, for example, in areas such as computing which has more dispersed markets).

Further research may also be needed in relation to some of the research hypotheses and questions of this study which were not fully answered. For example, these suggested that the socialist government could act to reduce some of the negative social consequences that might arise from a more dynamic and market oriented economy. The detailed empirical focus of this study did not allow this to be addressed directly. For example, further work could address to the extent to which the Chinese government has been able to provide telecommunications services to the entire nation in a way which can help to reduce the gaps between rich and poor and between more and less developed parts of China, rather than to widen them; and the interplay between market forces and the state play in these development.

Following on from this are questions about the role of the state. The study showed that the state is not able to carry out the kinds of effective, rational intervention envisaged under models of socialist planning, but is instead, strongly constrained by the knowledge and information it possessed and in its powers. The structure and operation of the state and broader political culture are relevant to discussion of state intervention. In particular, issues deserving further investigation include the roles of different sections of the state (which is divided into central and local levels and different functional areas) and how they work together. Different government policies can have considerable consequences for national innovation patterns, regarding investment, financial incentives for innovation, the development and application of technological competencies, as well as the stability of the society and the quality of people's life. It will be useful to address, through comparative analysis, the approaches of governments in developing country, and in particular to examine how they balance the interests of individuals and the nation; short term and long term objectives; and economic efficiency and public interests, as these are crucial for the formulation of government policies and development strategies.

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APPENDIX:

Abbreviations and Acronyms

BHCA	Busy hour call attempts - a measurement of call processing power
BTM	Bell Telephone Manufacturing Company
CAE	Customer Application Engineering
CCG	Communal Co-ordination Group
CCITT	Comité Consultatif International Télégraphique et Téléphonique
CDE	Country Development Engineering
CIT	Centre of Information Technology in Zhengzhou Institute of Information Engineering of the People's Liberation Army
COCOM	Co-ordinating Committee for Multinational Export Control
DCs	Developing Countries
DGT	Directorate-General Telecommunications
IN	Intelligent Networks
ISDN	Integrated Services Digital Network
ISO	International Standard Organisation
ITC	Indigenous Technological Capability
ITT	International Telegram Corporation
LED	light emitting diode
LSI	Large Scale Integrated (chips)
LTEF	Luoyang Telephone Equipment Factory of MPT
MMEI	Ministry of Machine Building and Electronics Industry
MPT	Ministry of Posts and Telecommunications
NICs	Newly Industrialised Countries
PABX	Private Automatic Branch Exchanges
PDSS	Public Digital Switching System
PTA	Posts and Telecommunications Administration
PTIC	Posts and Telecommunications Industrial Corporation
R&D	Research and Development
RASM	Remote Autonomous Switching Module
SST	Social Shaping of Technology

Selective Interview List

A non-Shanghai Bell engineer working at the workshop of the Operation Department, Shanghai Bell, interviewed on 6.11.1992.

Bao, Yu Tong, Director of Beijing Wire Communications Factory (manufacturing HJD-04), MMEI, interviewed on 14.4.1993.

Buo, Fu Dong, Director and General manager of LTEF, interviewed on 22.4.1993.

Cao, Wei Qian, Software Engineer, New Production Integration Engineering Department, Shanghai Bell, interviewed on 1.2.1993

Chen, Yun Qian, Chief Consultant, (former Director), Research Centre for Economic and Technology Development, MPT, interviewed on 16.4.1993.

Chen, Xu Hong, Chief Engineer of Hangzhou Telecommunication Equipment Factory (manufacturing HJD-04), MPT, interviewed on 22.10.1992.

Cui, Jing Yang, Manager, Beijing Long-term Data Technology Corporation, PTIC, interviewed on 6.4.1993 ,

De Graeve, (Belgian) Director and General Manager of Shanghai Bell, interviewed on 2.11. 1992 and 10.2.1993.

Ding, Dan Ni (woman), Department of Science and Technology, MMEI, PRC, interviewed on 12.4.1993.

Ding, Xue Zhong, Deputy Manager of Directorate Office, LTEF, interviewed on 2.4.1993.

Fan, Li Zhong, Chief Engineer at PBA Test, Shanghai Bell, interviewed on 6.11.1992.

Fan, Zheng Shi, Deputy Manger of Directorate Office, LTEF, interviewed on 2.4.1993.

Feng, Ji Chun, Deputy Chief, the Department of Fundamental Research and High Technology, The State Science and Technology Commission, PRC, interviewed on 8.4.1993.

Feng, Xin Yi, Deputy Manager, Chief Engineer, the Engineering Department, LTEF, interviewed on 24.4.1993.

Gu, Chong Wei, Chief Senior Engineer, Senior Technical Consultant, Shanghai Bell, interviewed on 2.2.1993.

Guo, Jing (woman), Deputy Manager , Financial Department, LTEF, interviewed on 23.4.1993.

Han, Fu Er, Senior Engineer (Consultant for Shanghai Municipal Science and Technology Committee), Shanghai Science and Technology Information Institute, interviewed on 3.2.1993.

Hu, Chuan Tai, Deputy Manager, the Department of Sales and Marketing, LTEF, interviewed on 27.4.1993.

Ji, Fu Sheng, Deputy Director, the Department of High Technology, State Science and Technology Commission, PRC, a short chat on 8.4.1993.

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Jiang, Ping, Manager, vice chief engineer, the Department of Production Quality Control, LTEF, interviewed on 27.4.1993.

Jiang, Yong, Deputy Director, the Planning Division in Science and Technology Department, MPT, interviewed on 8.4.1993.

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Liu, Shi Bin, Deputy Manager, the Production Department, LTEF, interviewed on 22.4.1993

Liu, Xi Ming, Chief Engineer, Senior Principal Engineer (leading switching specialist, leading also the project of DS-series development), No.1 Research Institute of the Ministry of Posts and Telecommunications, interviewed on 4.2.1993.

Luo, Wei, Deputy Manager, Engineering Department, Shanghai Bell, interviewed on 10.11.1992.

Peng, Bang Ying, Director of the Institute of Date Communication Engineering, LTEF, interviewed on 24.4.1993.

Prof. Wu, Jiang Xing, Director of CIT in Zhengzhou Institute of Information Engineering of People's Liberation Army, interviewed on 26.4.1993.

Qian, Zong Jue, professor, General Engineer, Department of Science and Technology, MPT, interviewed on 17.4.1993.

Rong, Li Lai (woman), Senior Engineer, Manager, Localisation Department, Shanghai Bell, interviewed on 28.2.1993.

Schelfhout, Rik (Belgian), Director of Engineering Department, Shanghai Bell, interviewed on 12.11.1993.

Shen, Yan He, Manager of personnel Planning & Education at Personnel & Administration Department, Shanghai Bell, interviewed on 3.11.1992.

Shen, Yu Wen, Engineer Software Implementation Manager New Product Integration Engineering Department, Shanghai Bell, interviewed on 2.2.1993.

Tang, Jian Xin, Deputy Division Chief Engineer, Transportation and Department, State Planning Commission, PRC, interviewed on 10.3.1993.

Tang, Ting Long, Vice Chief Engineer of Shanghai Telecommunications Administration, interviewed on 10.2.1993.

Teng, La Qiang, Director, Marketing and Sales Department, Shanghai Bell, interviewed on 28.2.1993.

Wang, He Ping, Engineer, Production Department, LTEF, interviewed on 27.4.1993.

Wang, Jing Hai, Manager of Production Department, LTEF, interviewed on 22.4.1993.

Wang, Manager of Personnel Department, LTEF, interviewed on 23.4.1993.

Xie, Xiao An, Chairman of the Board, Beijing International Switching System Corporation Ltd, (leading switching specialist, former Chief Engineer of Directorate-General of Telecommunication, MPT), interviewed on 14.4.1993.

Xu, Yan Wen, Vice Director, Engineer, Department of Science and Technology of The State Planning Commission, PRC, interviewed on 12.4.1993.

Xu, Yu Min, Senior Engineer, Director of Technology & Service Department, Science and Technology Information Centre, MPT, interviewed on 9.4.1993.

Xu, Zhi Qun, Deputy Manager of Engineering Department, Shanghai Bell, interviewed on 30.1.1993, 12.11.1992, 1.2.1993.

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Zeng, Yu, Deputy Manager, Department of Operational Finance, PTIC, MPT, interviewed on 16.4.1993.

Zhang, Feng Zhou, Director, Beijing Long-term Data Technology Corporation, PTIC, interviewed on 6.4.1993 and 16.4.1993.

Zhang, Manager of the Planning Department, LTEF, interviewed on 23.4.1993

Zhong, Xiao Jun, Vice Director, Senior Engineer, LTEF, interviewed on 29.3.1993.

Zhou, Zheng Min, Chief Financial Officer, Senior Accountant, PTIC, MPT, interviewed on 16.4.1993.

Zhu, Cheng Min, Chief Engineer, LTEF, interviewed on 21.4.1993.

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